PRACTICAL DRAUGHTSMEN'S WORK

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$25—

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PRACTICAL DRAUGHTSMEN'S WORK

WITH NUMEROUS ENGRAVINGS AND DIAGRAMS

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PREFACE.

Practical Draughtsmen's Work contains, in a form convenient for everyday use, a comprehensive digest of information, contributed by experienced draughtsmen, scattered over the columns of Work and Building World, two weekly journals it is my fortune to edit, and supplies concise information on the general principles and practice of the art on which it treats.

In preparing for publication in book form the mass of relevant matter contained in the volumes, much of it necessarily had to be re-arranged and re-written. The contents of this book consist substantially of several series of illustrated articles by Prof. Henry Adams, originally contributed to Work and Building World. The writings of many other contributors are so blended that it is difficult to distinguish any for acknowledgment.

Readers who may desire additional information respecting special details of the matters dealt with in this book, or instruction on any building trade subjects, should address a question to Work or Building World, so that it may be answered in the columns of one of those journals.

P. N. HASLUCK.

La Belle Sauvage, London,

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PRACTICAL DRAUGHTSMEN'S WORK.

CHAPTER I.

DRAWING BOARDS, PAPER AND MOUNTING

THIS book deals with the principles upon which mechanical and architectural drawings are made, and it is proposed, in the following chapters, to give a course of practical instruction in technical drawing as applied to the constructive arts. This branch of drawing does not aim at producing pictures so much as at showing conventional representations which shall enable other persons to construct precisely and exactly what the designer intends, in shape, size, and arrangement. The primary essentials are accuracy and neatness. An inaccurate drawing invites bad workmanship, and one not neatly made at the least leaves a doubt as to what is required.

Though it may occur in business that many things have to be hurried over for want of time, in learning a subject the student should not be satisfied unless each portion of his work is an improvement upon the last, and is the very best he is able to do; speed can always be superadded to accuracy if the latter is mastered first, but the order can never be reversed.

To describe the principles involved in making a mechanical or architectural drawing would necessitate a treatise on plane and solid geometry and projection that would be out of place in a book which is intended to deal only with the practical operations of the drawing-office. However, it should be understood that, to be in a position to do any but the very simplest work, a certain amount of geometrical knowledge is a necessary part of the draughtsman's equipment, and this must be acquired by a systematic study of that branch of science.

To commence draughtsmen's work a large assortment of

instruments is unnecessary, and even undesirable, the fewer and the simpler they are the better, provided they are efficient. Of course, a drawing-board, a T-square, and two set squares will be required, with drawing pencils, indiarubber, and drawing pins for holding down the paper, which may be cartridge paper. If a drawing-board 16 in. by $22\frac{3}{4}$ in. is employed, sheets 15 in. by 22 in. (half imperial size) will be found suitable. The ordinary drawing instruments, including bows for ink and pencil, will be required ; but when the reader has mastered the contents of this book he will be able to decide for himself here. We need go no further than to advise a beginner not to buy cheap tools. A set of pearwood French curves, a foot rule, or a set of scales, will be handy, while, for those who prefer it, a steel scale can be obtained.

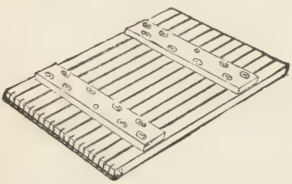


Fig. 1.—Back of Battened Drawing Board.

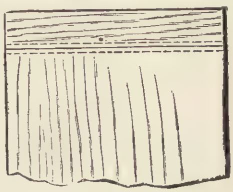


Fig. 2.—Edge of Clamped Drawing Board.

The first thing necessary is a drawing-board, which should be made about an inch longer each way than the largest sheet of paper in general use. If the sizes of the drawings vary considerably, it will be convenient to have large and small boards to suit. The usual method of constructing the ordinary board is shown in Fig. 1. The wood should be fairly stout, but not too hard, so that the pins can be inserted and withdrawn with moderate ease ; the grain should run lengthways of the board. The two battens should be screwed on underneath, and transversely to the grain of the other wood, to stiffen the board and prevent warping. All woodwork in course of time shrinks to a greater extent across the grain than it does in the direction of the grain, so it is advisable for the screws securing the battens to the board to work in slots, as shown on an enlarged scale in Fig. 2. The board is thus allowed to shrink and swell without unduly straining the screws or battens. In properly seasoned timber the shrinkage will be slight, and care should be used to secure wood suitable for the purpose. To prevent warping

through expansion and contraction, drawing-boards are sometimes grooved on the back, half-way through the thickness, at intervals of about 3 in. or 4 in. from end to end, as shown in Fig. 1. Some boards have hardwood slips glued into grooves at the end, as shown by Fig. 3. These slips are to guide the stock of the T-square, and saw kerfs should be run through them at intervals of about 3 in. (B B, Fig. 3) to prevent the slips being forced out of position by unequal shrinkage. Smaller boards can be stiffened by clamping a strip of wood about 2 in. wide transversely on each end of the board, as shown in Fig. 2.

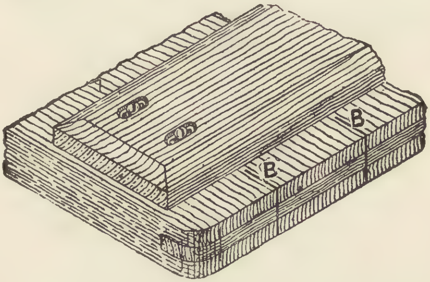


Fig. 3.—Enlarged Corner of Drawing Board.

All drawing-boards should be planed level on both sides, and squared exactly so that the opposite edges are parallel, and the adjacent ones at right angles to each other. A drawing-board that has suffered from rough usage and become indented may be renovated and the bruised grain of the wood can be raised by well wetting it and placing on the dents several thicknesses of brown paper previously soaked in hot water. A piece of dry paper is placed on these, and a hot flat-iron laid on the whole causes the dents to swell up. When the board is dry, a shaving or two can be taken off with a smoothing-plane, and the board will be as good as new.

Draughtsmen generally prefer to stand to their work, because in the various operations of drawing and finishing a large plan operations are seldom confined to one part of the paper only, and it is necessary to alter continually the position of the body to obtain a proper command of the work. However, for some drawing it is possible to work while seated, and a stool is used by some draughtsmen.

The position and arrangement of the office in which the draughtsman has to work is a matter of some importance. For working in the daylight, a window facing north, with the light rather on the left-hand side of the board, as shown at Fig. 4, is about the best arrangement, and when artificial light is employed the lamp should be placed over and beyond the top left-hand corner of the board. A pair of supports for inclining the board from 15° to 20° by placing one under each end, as shown in Fig. 4, is a convenience. This slope of the board allows the

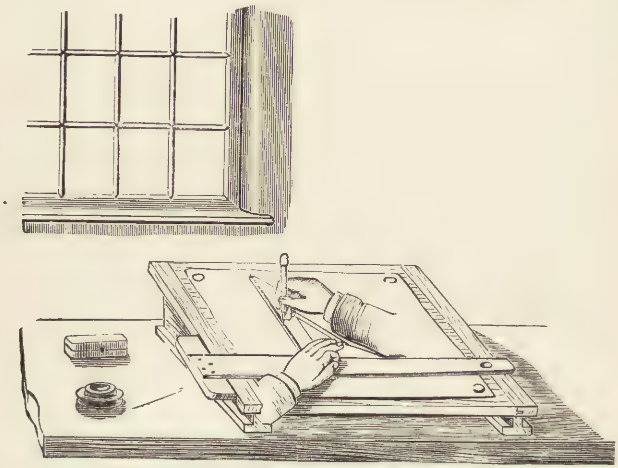


Fig. 4.—Position of Draughtsman's Board.

draughtsman to work with greater ease, especially at the far side of the board.

The height of the desk or table on which the drawing-board has to be placed while the draughtsman is at work will be determined by the size of the drawings. When the paper is under imperial size, one may sit down while at work, and a height of about 2 ft. 6 in. from the floor to the surface of the drawing-board at its lowest edge, with the board sloping at an angle of about $1\frac{1}{2}$ in. in a foot, will be a convenient arrangement for most workers. With larger drawings the draughtsman will find it most convenient to stand while at work; and to reach the upper farther part of the board it will be necessary to use a

footstool. Fig. 5 gives a section through a fixed desk or counter for a drawing-office. The space underneath is often utilised by being fitted with drawers to hold drawings; but when this is done, sufficient knee room should be allowed, by keeping the fronts of the drawers well back from the edge of the desk. When the drawing-board is placed on this desk, the slope for convenient working may be obtained by placing under the back edge a strip of wood about $2\frac{1}{2}$ in. square (A, Fig. 5), and as long as the board, the slope of which may be regulated by sliding this strip backwards or forwards.

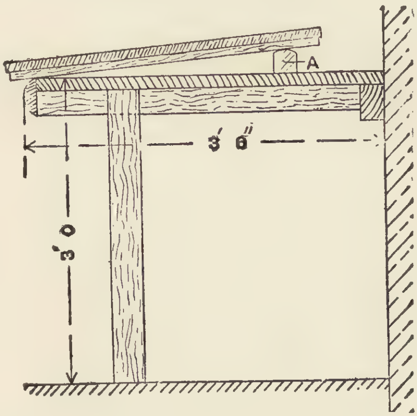


Fig. 5.—Section of Fixed Table and Board.

The paper most suitable to be used depends a great deal on the kind of drawings to be made. For fine, accurate work smooth or medium surface paper is the best. But for a coloured drawing made more for show than accuracy, rough paper should be used, as the colour runs better on it. The papers in general use in the drawing office are "cartridge," a machine-made paper, used for work where an ordinary finish is required; and hand-made for superior work. Generally one side of the "cartridge" is finished to a smoother surface than the other, and the smooth surface is the one usually chosen for drawing on; it is not suitable for colouring. Hand-made paper is of a finer and stronger texture, and has a hard surface. Both sides are much alike in appearance, but the surface intended for drawing on

may be ascertained by holding the paper up to the light and observing the letters of the water-mark, which reads in the right direction when looked at from the working surface. For drawings which have to be submitted to much handling, or which it is desired to preserve in good condition for many years, it is usual to use drawing-paper mounted on holland or linen.

The sizes of drawing-papers vary to the extent of half an inch or so with different makers, but the usual sizes are as follows :—

USUAL SIZES OF DRAWING-PAPER.

Name of Paper.	WHATMAN'S.		JOYNSON'S.	
	Size to Inches.	*lb. weight to Ream.*	*Size to Inches.*	*lb. weight to Ream.*
Foolscap	$17 \times 13\frac{1}{2}$	18	—	—
Demy	$20 \times 15\frac{1}{2}$	25	$20 \times 15\frac{1}{2}$	42
Medium	$22 \times 17\frac{1}{2}$	34	—	—
Royal	24×19	44	24×19	44 to 60
Super Royal ...	27×19	54	—	—
Elephant	28×23	72	—	—
Imperial	$30\frac{1}{2} \times 22\frac{1}{2}$	72	30×22	72 to 140
Colombier	$34\frac{1}{2} \times 23\frac{1}{2}$	100	—	—
Atlas	34×26	100	—	—
Double Elephant ...	$40 \times 26\frac{3}{4}$	133	40×27	140 to 230
Grand Eagle ...	$42\frac{3}{4} \times 28$	150	—	—
Antiquarian ...	53×31	240	$52\frac{1}{2} \times 30\frac{1}{2}$	250
Emperor	—	—	72×48	535
Double Emperor ...	—	—	96×69	1025

These papers can be obtained in three surfaces—N (natural surface), HP (hot pressed or smooth surface), R (rough surface). The natural-surface paper should be employed for general work, as it will stand much rubbing out and will take colour well. The hot-pressed surface paper is the best for fine pencil and ink drawings that are not coloured. The rough paper is used by artists for water-colour drawings and sketches.

Paper of the standard sizes is to be bought ready mounted on cloth, and for specially large plans either "cartridge" or superior paper can be bought in a continuous roll in various widths up to 60 in.

A useful paper is that sold ready divided by faintly ruled lines into squares of various sizes, generally into inches and eighths or tenths, the inches themselves being indicated by a thicker line. It is of service in enlarging or reducing by the method of squaring described on p. 150, and even more so in sketching directly to scale, as the squares enable any dimension to be drawn correctly at once. It is applicable alike to the uses of the machine draughtsman in sketching details of machinery to correct scale and the civil engineer for plotting small surveys.

Tracing-papers are made in a variety of thicknesses, tints, and textures. They have usually one side smoother than the other, and are sold in continuous rolls measuring 21 yd. or 22 yd. in length, and varying in width from 30 in. to 44 in. To make tracing-paper tissue paper is coated, by brushing or sponging, with a mixture of 1 part of boiled linseed oil to 5 parts of turpentine. Each sheet is done separately, and hung over a line to dry. When the clear oily marks disappear it will be ready for use. Tracing-linen or tracing-cloth is obtainable in about the same sizes. It is made generally with one side glazed and the other rough, and occasionally with both sides glazed. The selection of the side to be used for drawing on must be left to individual discretion, some preferring one side, some the other. The rougher side is easier to work on, as it takes both ink and colour easily, but a much neater and more effective tracing is produced on the glossy side, the colouring being done on the rough surface. The rougher surface is more easily soiled than is the smooth.

It is a usual custom, before commencing a mechanical drawing, to secure the paper to a drawing-board, so as to keep it flat and in the same position relative to the edges of the board from which right angles are set off with the T-square. The most simple method is by placing lead weights on the corners of the paper. If the drawing is to be made in pencil only, then the paper can be fastened to the board by pins. The most convenient way to do this is to place the paper squarely on the board, and put a drawing-pin into the top left-hand corner; place the T-square along the top edge of the paper: take hold of the bottom right-hand corner of the paper and move it up or down till the top edge of the paper becomes parallel with the edge of the T-square, when another drawing-pin can be inserted in the bottom right-hand corner, and then two others in the remaining corners.

The principal point to be attended to in the choice of drawing-pins (see Figs. 6 to 11), is that the head shall be so shaped as not to interfere with the passing of the blade of the T-square over it; and for this reason the dome-shaped head shown in Fig. 7 will be found to answer admirably. Another good section of head is shown in Fig. 8; while the "flat heads," shown in Fig. 9, are not so good as the two last mentioned. A cheap and fairly effective drawing-pin is now made by punching out of a steel disc a tongue, and bending it downwards to form a pin, as shown in Fig. 10; while Fig. 11 shows a form in which the three corners of a triangular sheet of thin steel are bent downwards to form three pins to pass through the paper. For a good drawing-pin, it is

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Figs. 6 to 11.—Drawing Pins.

desirable to have the head at least $\frac{3}{4}$ in. in diameter, and the pin not much tapered, or it will not hold tightly in the drawing-board and this is necessary.

If the drawing to be inked in, coloured, and dimensioned is an elaborate one, and likely to be a long time in hand, the paper should be strained on the board. To do this, first ascertain which is the correct surface for drawing on, and lay the paper face upwards on the board, then bend up a margin strip $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. wide all round the sheet. Turn over the paper, and well damp the back of it with a sponge and cold water taking care to leave the margins free from moisture. After thoroughly damping, sponge off the superfluous water, and turn the paper right side up on the board, taking care not to wet any part of the board where the glue or paste for fastening the edges has to come. Lay a wooden straight-edge along the paper, about 1 in. from the top edge, bend the dry margin over the straight-edge, so as to bring the under surface uppermost over the straight-edge, and pass over it a brush dipped in hot glue or paste (see Fig. 12). Turn the paper back again, and press the

glued margin into close contact with the drawing-board. Remove the straight-edge to the left-hand margin of the paper, and glue that in the same way, and afterwards proceed to glue down the other margins at the right-hand end and bottom edge.

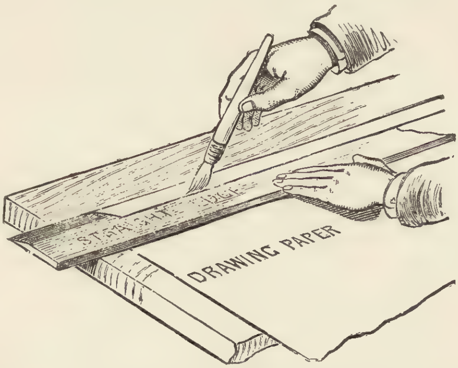


Fig. 12.—Pasting the Margin of Drawing Paper.

Now smooth down the paper, commencing in the centre of the sheet, with a clean dry handkerchief, working gradually towards the edges to expel the air. Then press the glued margins well on

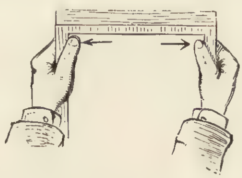


Fig. 13.—Fastening the Paper.

the board with the thumbs, at the same time drawing them apart, as shown by the arrows (Fig. 13). This operation should be repeated all round the margin, the thumbs being always opposite each other during the stretching process. Shoemakers' paste, which can always be obtained ready-made at any cobbler's shop or grindery store, is much stronger than the ordinary paste, but shares with that material and gum the defect of taking a long time to dry.

B

The wetting of the paper causes it to expand, so that it measures more in length and breadth than when dry. As the paper dries it will shrink, and as the edges are securely glued to the board, the paper will stretch itself very tight and flat. From this it will be understood that the more quickly the gluing is done the better, because if there be much delay, the paper will be partially dried before the margins are completely stuck. It is advisable to leave the board in a horizontal position, not standing on one edge, as the moisture may run down to the bottom margin, keeping one part of the paper wet longer than another. The drying should not be hastened by placing the board before a fire, which would probably dry the paper unevenly, and pull it into wrinkles. If the edges of the paper are not firmly glued to the board when the paper begins to shrink, they will be pulled from their support, and thus the paper cockled and warped.

Care must be taken that the drawing-board is not stained with ink, or this may get into the damp paper and spoil it. Some kinds of wood—teak, for instance—will stain the paper; therefore, when there is any doubt on this point, it is a good plan to put a sheet of common paper between the board and the drawing-paper. In stretching mounted drawing-paper on the board, glue will not be strong enough to hold the edges, and small tacks should be used for the purpose.

CHAPTER II.

DRAUGHTSMEN'S INSTRUMENTS.

In giving a brief description of some of the various instruments generally used in the drawing office, it may be advisable to remind the reader that it would take up more space than can be spared here to even mention and illustrate all the varied forms of the numerous instruments which are used by draughtsmen. Attention is devoted in this chapter principally to such appliances as may be considered comparatively indispensable. All the instruments generally used will be found illustrated and described in the catalogues issued by makers and dealers, who point out the several merits which are claimed for them. A great number of peculiar instruments and many patented articles will also be found in the manufacturers' catalogues, and although these are in many cases very useful in their way, most practical draughtsmen manage to do without them, and in this chapter it is proposed to deal only with those instruments that are usually necessary in the ordinary work of making a drawing.

Most makers stock three qualities of instruments, and it is advisable to buy the best that are made, called extra-quality instruments, as they will last a lifetime and the first cost is also the last.

Next in importance to the drawing-board, which has already been described in the preceding chapter, comes the T-square. Spanish mahogany is the best wood for large squares, and smaller ones may be made of pear tree or of mahogany, edged with ebony. Plain straight-grained wood should be selected for T-squares. Figured mahogany is more liable to warp, is difficult to plane, and wears to a ragged edge. The blade ought to be easily removable from the stock for the purpose of trueing up the edges.

The most approved pattern of T-square has a taper blade screwed on the top of the butt end, as shown by Fig. 14, p. 20. A parallel blade let into the butt is not so good. With the

former the set-square can slide over the butt, and still be kept against the blade; with the latter the set-square must be raised to pass over the butt, which makes it difficult to keep the set-square firm against the blade. However well seasoned the pear-tree or mahogany wood of which the T-squares are made, it will be found difficult to prevent it warping, and care should be taken to keep the squares in a place free from damp or excessive heat. The working edges of the butt and blade should be furnished with narrow strips of ebony slightly bevelled on the upper side. Some T-squares are made with parallel blades and shifting stocks, which may be adjusted to any angle. These are not popular with practical draughtsmen, who generally prefer to

Edge View of T-square.

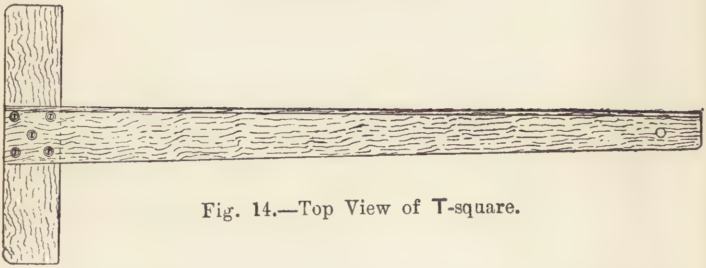


Fig. 14.—Top View of T-square.

use two set squares with which to draw lines at an angle. The T-square must be worked on the left-hand edge of the drawing-board, and it should be used for drawing horizontal lines only; the perpendiculars being always drawn by a set-square working against the T-square. A T-square used for vertical as well as horizontal lines would communicate to the lines in the drawing any slight inaccuracy in the truth of the edges of the board, as shown on p. 41.

The position of the left hand when drawing is shown in Fig. 52, p. 37, the left hand holding the set-square against the T-square, the thumb and forefinger pressing the blade on the paper, and at the same time holding the butt against the end edge of the board by a slight pressure towards the right.

Next in importance to the T-square comes a selection of set-squares. These are made of various materials, all of which have

certain objectionable features, but the best squares are those made of ebonite or vulcanite, as shown in Fig. 17. They are not liable to warp or to get out of square, but they collect dirt and smear the paper if not kept very clean, are liable to break if dropped or roughly handled, and the larger sizes are rather expensive. Framed set-squares (see Fig. 15) are made of three pieces of mahogany or other wood, edged with ebony. They are built up of three separate parallel pieces of hard wood, joined at the corners. By means of the open centre, a better hold of the set square can be obtained, and it can thus be moved about more freely, and held more firmly when once in its proper position for drawing. Framed squares are liable to get out of order if not made of carefully selected dry material. Common plain

Fig. 15.—Framed Set Square.

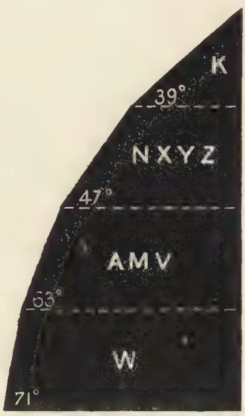


Fig. 16.—Set Square for Lettering.

squares, made of plain pieces of thin mahogany, pear-tree, or other woods, planed to the required angles, are liable to twist and warp when exposed to heat or dampness.

These squares have a hole, about $\frac{3}{4}$ in. in diameter, bored near the base, by which they can be manipulated, and which also enables them to be hung on a peg. Set squares are made of all angles, but for ordinary work two are generally sufficient, one with angles of 30°, 60°, and 90°, and one with angles of 45°, 45°, and 90°. Special set-squares are procurable,

adapted to the various pitches of roofs, slopes, and batters of embankments, angles of screw nuts, and other standard requirements. A set-square used in setting-out lettering is illustrated at Fig. 16.

When drawing a vertical line, the vertical side of the set-square should be turned towards the left, as shown at B, Fig. 17. When it is desired to draw lines against the sloping edge of the set-square this is reversed, as shown at A. In both cases the set-square serves as a rest for the draughtman's hand and protects the drawing.

Drawing pens and compasses form the most important instruments in the draughtman's outfit. Foreign-made cases of instruments, containing a large number of pieces, may be bought for a comparatively small sum, but cheap instruments are often

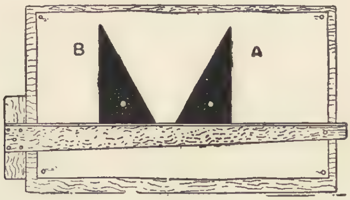


Fig. 17.—Use of T and Set Squares in Drawing.

worthless. The best plan is to buy of some well-known maker, and get instruments which the makers will guarantee to replace if not satisfactory. A case should be provided in which to keep the instruments, so that they shall be together and clean. Among working draughtsmen it is generally agreed that a beautiful, well-polished case crammed with the very best instruments of all and every kind, is not necessary for turning out a good drawing, and good work can be done by means of a few of the simplest and plainest instruments. It may not be out of place here to give the following hint to young would-be draughts men :—Do not waste a lot of money in getting together an elaborate and expensive box of instruments, many of which will afterwards be found to be not wanted. It is better even to buy singly just the instrument that is wanted as advance is made in the art of drawing. A strip of chamois leather and a pair of elastic bands make a case that serves all purposes; it keeps out

the damp and preserves the points, and possesses many distinct merits. No draughtsman need ever feel diffidence in walking into the best of drawing offices with such a little roll of instruments in his pocket. Empty cases may be purchased without the instruments. Some morocco-covered ones that go in the pocket have a neat appearance, take up but little room, and are not expensive. It is advisable to commence with a case that will contain the following, even if it is not filled up at first :—Half-

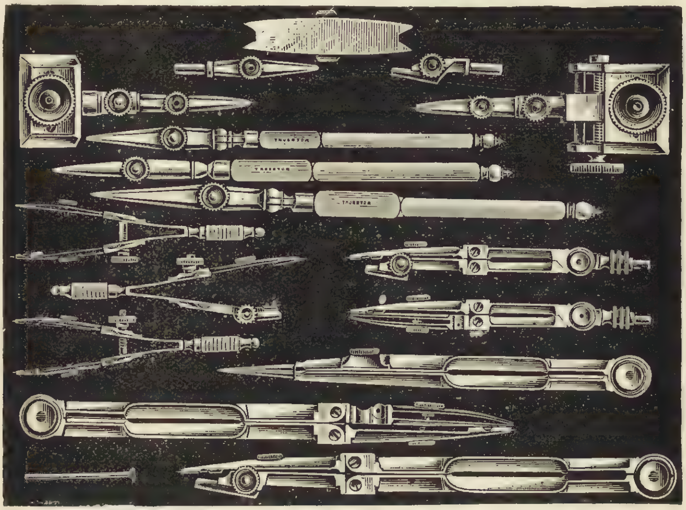


Fig. 18.—Serviceable Set of Instruments.

set of 6-in. compasses, with lengthening bar; ink and pencil bows; two drawing pens; set of three spring-bows; pricker and key. These instruments are sufficient for general work.

Fig. 18 illustrates the contents of an ordinary box of serviceable instruments. They comprise, commencing at the upper part :—One pair of 6-in. compasses with pencil point; one pair of compasses with pen point; one pair of 5-in. hair dividers; bow pen; bow pencil; set of three spring bows, comprising divider, pencil, and pen; three drawing pens; pair of beam-compass heads with screw adjustment and extra pen and penci joints, and screw key for adjusting the joints.

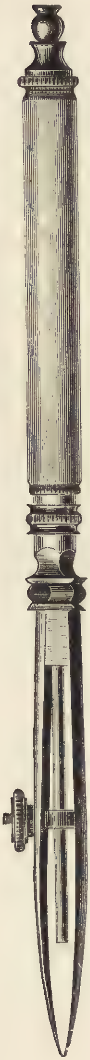


Fig. 19.—Ruling Pen.

A ruling pen of good quality should be selected, as it is the instrument with which most of the lines are inked in, see Fig. 19. This illustration shows a pen fitted with an ink reservoir in the handle, and it is particulariy useful for drawing lines that require much ink.

Pens with lift-up nibs, as shown at Fig. 20, are handy for setting and keeping clean. It is advisable to choose a ruling pen having one strong and rigid blade which will not bend with an increase of pressure against the edge of the set-square or straight-edge; flexibility would affect the regular thickness of the line which is being drawn. The handle shown in Fig. 21 has a square portion which is useful in preserving the proper direction of the nibs of the pen when drawing. This screw should be sufficiently loose for the draughtsman to open or close the nibs with the second finger, when holding the pen as shown in Fig. 82, p. 51, without lifting it from the paper. New pens are usually too tight, and a little oil will greatly improve the working of a tight screw, and the screw of all pens and spring dividers should be oiled occasionally, or in the course of time they may strip their threads. It is often convenient to be able to carry a drawing pen in the pocket ready for use, for much can be done with this instrument alone by a mechanical draughtsman who is also a good freehand draughtsman. A pocket drawing pen consists of a hollow handle in which the nib is carried secure from damage. When required for use, the nib is unscrewed, reversed, and again screwed into the handle.

For drawing parallel lines moderately close together, as in indicating roads, canals, or railways in maps and small scale plans, a double pen, such as is shown in Fig. 22, is convenient. It consists of two ruling pens, with a screw and a milled head for regulating the distance between them. It is particularly

useful where the lines to be drawn are curved or of irregular form.

A ruling pen especially designed for drawing curved lines is shown in Fig. 23. The handle is tubular, and through it there runs loosely the metal shank of the pen. At the top is a milled head, by which the pen can be clamped tight to the handle, and can then be used as an ordinary drawing pen. When the nibs

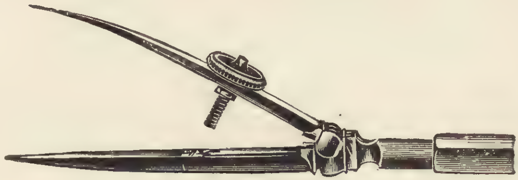


Fig. 20.—Lift-up Nib.

Fig. 21.—Square Handled Pen.

Fig. 22.—Double Ruling Pen.

Fig. 23.—Pen for Ruling Curves.

are free to revolve independently of the handle, they follow the direction of a curved line with great freedom, and although rather awkward to handle without practice, a swivel pen is convenient for the purpose of drawing lines against a curved guide.

Draughtsmen's ruling pens should always be cleaned after using, and for this to be done it is convenient, though not necessary, to have one of the nibs hinged so as to lift up and allow the dried ink to be scraped off the inner side of the nibs with a penknife. This hinge is shown in Fig. 25. A piece of chamois leather pulled between the nibs of the pen after using it, will generally be found sufficient. For scraping off hard dried

Indian ink, the thin blade of a penknife may be inserted between the nibs of the drawing pen, or a steel writing pen with half of the nib broken away may be used. The adjusting screw for setting the pen nibs to rule lines of various thickness is often made with its milled head too small. A good arrangement is to have the

Fig. 24.—Milled Head between the Nibs.

milled head placed between the nibs of the pen, as in Fig. 24, and these are adjusted by right and left-hand threads on the screw of which the milled head forms part. Some ruling pens are made with the ivory handle to unscrew and serve as a pricker or station pointer. This form weakens the instrument at the screwed joint, and there is little gained in providing in this way a simple tool which can, by driving a needle into a pen holder, by any draughtsman, be made in five minutes.

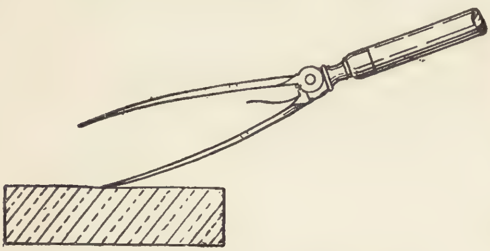


Fig. 25.—How to Set a Ruling Pen.

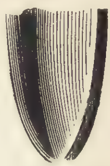


Fig. 26.—Point of Ruling Pen Enlarged.

The ruling pen is more used than any other drawing instrument, and occasionally it requires setting or sharpening. This is not a very difficult operation after a little practice, yet many draughtsmen make a practice of sending their pens to the instrument makers to be set. By taking out the screw and looking directly at the point of the pen, it will be seen that the worn part has a flattened surface. If only one nib of the pen has become worn shorter than the other, hold the pen upright on the stone (fine Turkey or Arkansas preferred) and grind both nibs level before removing the screw and setting. To set the pen place the nib on an oilstone in the position shown in Fig. 25. Move the pen

backwards and forwards, at the same time slightly rocking it horizontally and vertically. Wipe and examine the pen occasionally, and stop just short of bringing the point to a sharp edge. If the nibs are too sharp, they will cut the paper, and it will be necessary to take off the keen edge by using for a few minutes on a piece of brown paper. A pen of good hard steel will keep its edge for many months without being set. In setting the pen, each nib should be brought to a rounded chisel edge and both nibs should be of exactly the same length, as

Fig. 27.—Dotting Pen.

shown enlarged at Fig. 26, so that when the pen is held upright they shall both bear evenly on the paper.

Dotting pens are used for the purpose of drawing lines composed of dots and of dashes, the ordinary pattern being such as is shown in Fig. 27, where a small roller or rowel is fixed between the nibs of the pen. Ink is supplied to this roller which has its edge cut to the desired pattern of dots, and imprints them on the paper as it is rolled along. Several patterns of dotting wheels or

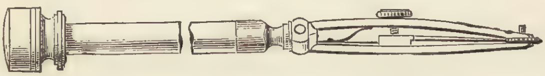


Fig. 28.—Dotting Pen with Midrib.

rollers are usually supplied with the pen, and are stored in the cavity shown at the top of the handle, covered by a screwed lid. Another pattern, shown in Fig. 28, is provided with an internal tongue or midrib coming almost into contact with the dotting wheel. It is claimed that with this pen sufficient ink can be retained to draw a dotted line 60 feet in length. Other descriptions of dotting pen have been produced, some being elaborate pieces of mechanism actuating an ordinary pen by a cam movement, which derives its motion from a roller moved by drawing the instrument along the desired line. It is generally admitted by experienced draughtsmen that a

dotting pen is an instrument which can easily be dispensed with, and it is rarely used by an expert.

Compasses generally include dividers and pen and pencil compasses. The ordinary forms of these instruments are shown on p. 23 by the three lower Figs. in the illustration, and need but a short reference here. This instrument is for setting off long distances and for making large circles. Besides the dividing leg, it should be fitted with interchangeable legs for pen and pencil, and also a lengthening bar, for use when extra large circles are to be made.

Compasses are made with plain points and needle points.

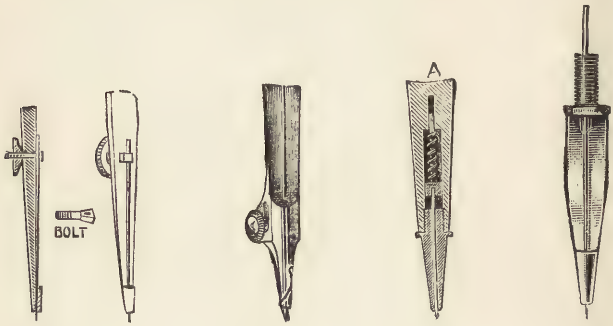


Fig. 29. Fig. 30. Fig. 31. Fig. 32.

Needle Points for Compasses.

The latter are far preferable, as they do not greatly enlarge holes in the paper when drawing a large number of concentric circles. Triangular points, which are often found on inferior instruments, have a very bad tendency to bore holes in the paper. The needle points in Fig. 29 are very good, provided the hole in which the point of the needle fits is accurately drilled, so that the needle cannot shake, as in this case there is no tightening arrangement; a small bolt is pierced at one end by a hole, through which the needle passes—a nut on the outer end of the bolt enables the needle to be firmly clamped against the leg of the instrument. The screw above only prevents the needle from slipping backwards, not from shaking sideways. Probably the safest needle-holder is that shown at Fig. 30, where the

hollow holding the needle is split, and the needle can be adjusted by tightening and loosening the screw. The needle in this point can be adjusted so as to project a very little beyond the shoulder, which acts as a stop, to prevent the needle penetrating too far into the paper. Figs. 31 and 32 show other forms of needle points that are sufficiently explained by the illustrations.

Compass legs are made both with and without a leg joint. Fig. 18 shows a joint in each leg which is wanting in some instruments. These joints are useful, as by their means the point of needle and pencil can be kept almost vertical as shown by Fig. 86 on p. 54. An unjointed leg forming the centre point of a large circle would be very much inclined, and therefore have a tendency to slip, at the same time wearing a large hole in the paper.

Some compasses are so arranged that the legs, after being inserted in a socket, are fastened by a screw with a milled head, and it is often a source of vexation to find this screw continually loosening. A better form of joint is shown in Fig. 33, which

Fig. 33.—Socket Fitting for Compass Legs.

simply depends on an accurate fit and friction to keep the parts steady, and if this is well made, it is a much better joint than the former. The part marked B (Fig. 33) is a flat piece of steel inserted in the circular piece C on the leg, to prevent the detachable portion, which is shown in section, from turning round.

To test the joint of a pair of compasses, open them slowly to their fullest extent. If they open and close smoothly, without unevenness in any part, the joint may be considered to be good, but if one part works tightly and another loosely, the compasses should be rejected. Another point is to see that the interchangeable legs fit accurately, leaving no play whatever. Electrum is the material best suited for their construction, on account of its lightness and freedom from liability to tarnish. The legs should be double-jointed; with these it is possible to keep both points at right angles to the paper—a great advantage in good work; and those with needle points should be chosen, as they cause less damage to the drawing-paper, and admit of greater accuracy in their use.

Hair dividers are useful for comparing or setting off small distances with great accuracy, though with care an equal amount of accuracy can be obtained with the ordinary dividers. Hair dividers have one leg fitted with a spring, as shown in Fig. 34, with an adjusting screw. The points are first set approximately to the desired measurement, and the final adjustment is made by turning the milled head of the screw.

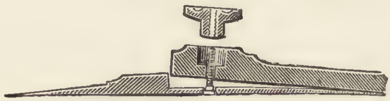


Fig. 34.—Leg of Hair Dividers.

Proportional compasses are specially for the purposes of reduction and enlargement. From Fig. 35 it will be seen that the two arms of the compasses are slotted to receive the sliding blocks which form the pivot. By means of the milled head shown in the figure, this pivot can be clamped in any position in the slots, and the relative opening of the two ends of the compasses is regulated by the position of this movable centre. A scale engraved on one of the arms indicates the position to which the centre

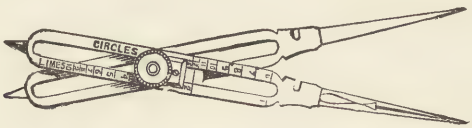


Fig. 35.—Proportional Compasses.

pivot is to be set in order to give the required proportion between the openings of the two ends of the instrument. Thus, if the line engraved on the sliding centre be set to the line figured 3 on the scale, the opening at one end of the compasses will be three times as large as at the other. If the centre is to be set to the line 4, one opening will be four times as large as the other, and to enlarge or reduce any measurements on a drawing four times, it is only necessary to take the measurements from the original drawing with one end of the instrument and transfer them to the new drawing with the other end. The better

quality of proportional compasses have additional scales engraved upon them, giving the ratios of diameters of circles, areas, and other tables, and some have also a rack and pinion motion, for setting the centre pivot in its correct position.

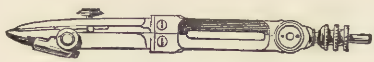


Fig. 36.—Bow Compass.

Bisecting compasses are a simple form of proportional compasses, intended for measuring and setting off lengths only in the proportion of 1 to 2. They are, accordingly, provided with a fixed pivot, and have no means of adjustment.

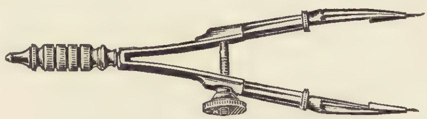


Fig. 37.—Spring Bow Dividers.

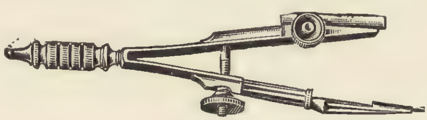


Fig. 38.—Spring Bow Pencil.

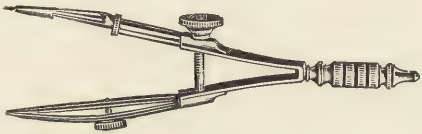


Fig. 39.—Spring Bow Pen.

Bows (Fig. 36) are used for describing smaller circles, and these may be obtained also either single or double jointed, or with plain or needle points. Double-jointed bows, with needle points, are well worth the extra cost.

Spring bows are used for making small circles. They are sold

in sets of three, comprising dividers, pen bow and pencil bow. A set is illustrated by Figs. 37, 38, and 39.

A form of spring bow which is known as the "pump" pen is shown in Fig. 40. In this, one leg consists of a straight rod about 4 in. long. The pen or pencil forms the other leg, which revolves freely around the centre rod. The method of using is shown at Fig. 122, p. 69. The pen and pencil points are interchangeable, and a larger circle can be described with this instrument than with the

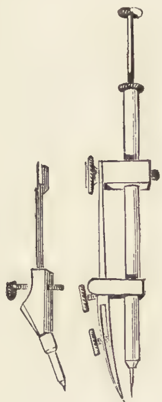


Fig. 40.—Pump Bows.

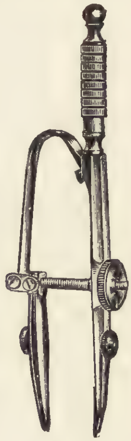


Fig. 41.—Spring Bows.

ordinary spring bows. Fig. 41 shows another form of spring bow with which larger circles can be drawn.

Beam compasses are useful for striking very large circles. Those fitted with a socket to take a lath are the cheapest, and are suitable for all practical purposes. It is advisable to have one end fitted with a screw adjustment, as this saves a lot of trouble in setting to the required radius.

Beam compasses are somewhat costly, though not difficult to make. The home made beam compasses about to be described are generally used in preference to the superior and orthodox kind, principally on account of their great lightness. The beam was made from an old boxwood 18-in. scale that was badly damaged on one edge. This was ripped

down the middle and trued up; the scale on the upper edge afterwards proved to be of great use in adjusting the two points.

Having made the beam, cut two strips of tin about $\frac{5}{8}$ in. or $\frac{3}{4}$ in. wide, and long enough to go round the beam, and make a lap-joint as shown in Fig. 43 and also in all the other figures; bend these strips tight round the beam, so that they will just slip, and solder the lap-joint. From two other strips of tin bend up two split tubes, one as in Fig. 42, to fit a drawing pen, the other to fit a

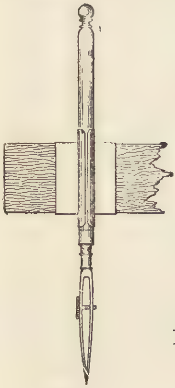


Fig. 42.

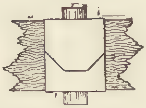


Fig. 43.

Fig. 44.

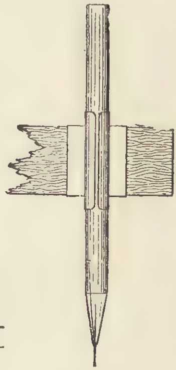


Fig. 45.

Fig. 42.—Pen Point. Fig. 43.—Back of Holder. Fig. 44.—Section through Beam. Fig. 45.—Needle Point.

BEAM COMPASSES.

short piece of ordinary wooden penholder. These split tubes should be soldered to the two tin straps, on their plain sides, in the positions shown in Figs. 42, 43, and 45.

The piece of wooden penholder that fits the other split tube, and forms the needle-point, should be about the same length as the drawing-pen. Into one end of it drive part of an ordinary fine sewing needle, point outwards, then shape the penholder as a pencil is sharpened (see Fig. 45), and the needle-point is complete. When not in use it is well to keep a bit of cork stuck on the end of the needle-point for protection. When fixing together for use, as in Figs. 42 and 45, the pen and needle-point should be kept perpendicular, and in the right position. Should the straps and split tubes at any time work a little loose, they can easily be tightened by a slight pinch with the thumb and finger.

Should a pencil-point be wanted instead of a drawing-pen, it is easy to get one to fit well into the split tube made for the pen.

A cheap makeshift beam compass, with which good work can be done, may be made out of a blind lath and two good-sized

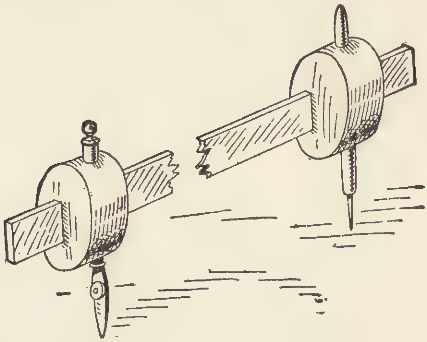


Fig. 46.—Cheap Beam Compass.

corks, such as are used in pickle bottles. Holes for the reception of the lath and drawing pen, and also for the pricker or needle stuck into a penholder, are burnt and cut through the corks as

Fig. 47.—Curve Bow.

shown in Fig. 46. The cork takes a good grip of the lath, and the instrument is quite steady and pleasant to work with.

For very flat curves, a Curve Bow (Fig. 47) is sometimes used. It consists of two wooden beams, one being a rigid piece of hard wood with a screw working through the centre; the other a thin, pliable strip, which is bent by the turning of the screw. Within narrow limits, this instrument can be adjusted to varying radii, but if the strip be bent beyond a moderate extent the curve loses its circular character and becomes approximately parabolic.

For inking-in large curves, such as those of elliptical arches, "splines" are very useful. These may be made of lancewood,

hickory, or ash, about $\frac{1}{4}$ in. square. They are bent to the required curve, and kept in position by means of weights.

Railway curves (Fig. 48) may be obtained in cardboard, pear-

Fig. 48.—Railway Curve.

wood, or ebonite, with radii varying from $1\frac{1}{2}$ in. to 240 in., each curve being numbered according to its radius in inches. These are also useful for setting out flat curves, such as those of camber

Fig. 49.—French Curve.

arches and the lines of railway sidings.

When curves of ever-varying radius are to be inked in, the French curve, shown in Figs. 49 to 51, is used. This consists

Fig. 50.—French Curve.

of a flat piece of hard wood cut out into more or less intricate patterns, with almost any curve between a straight line and a very small circle. When inking in a curve on the drawing with the curve, it is necessary to find some portion of the wood which

exactly coincides with a certain part in the drawing; this should be inked in with the pen, the curve should be removed, and some other portion of it found to continue the curve from the last point. This process is shown in Fig. 134, p. 77. French curves are made in pearwood, in a great variety of shapes. Figs. 49, 50, and 51 show useful patterns, and a few of these in varying sizes will be sufficient for most purposes.

In cases where there is much repetition of a complicated detail in drawing, it is a saving of time to make suitable templates out of soft wood, with which the outlines can be rapidly

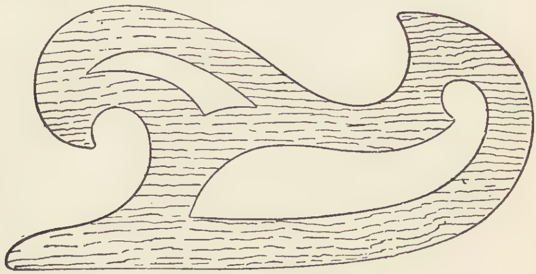


Fig. 51.—French Curve.

drawn by passing the drawing pen round them. Small templates can be shaped with a penknife, the curved portions being smoothed with a file and glasspaper.

In addition to the curves enumerated above, the draughtsman should provide himself with a few thin pieces of pearwood or mahogany, from which a template to suit any required sweep may be easily made with the penknife and a piece of glasspaper.

It should be remembered that a draughtsman who can strike in his curves with a steady freehand sweep often saves himself much piecing up of odd lengths of curves selected from the template, and is certain to obtain a more harmonious effect in the end.

The methods of using draughtsmen's instruments will be explained in the following chapters as opportunities offer.

CHAPTER III.

DRAWING STRAIGHT LINES.

It is presumed that the reader has procured a selection of the instruments already described, and that he is now desirous to attain skill in using them.

This course, outlined in this and the following chapter, while simple enough for youths yet at school, will be found equally suitable for adults who desire to make accurate working drawings, and who have had no preliminary training, and

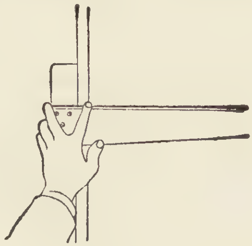


Fig. 52.—Method of Holding T-square.

for young professional draughtsmen who have not learnt the basis upon which their art depends ; it will also lead up to the drawing required by the Department of Science and Art in the subjects of machine and building construction.

To commence the practical work of making a drawing, set the drawing board on a flat table, and raise the back edge so that a sloping surface is presented to work upon. Place the paper about half an inch from the left-hand and bottom edges of the board, with the smooth side uppermost, and fix a drawing pin in the top left-hand corner of the paper, put in square and pressed firmly down. Now take the T-square, holding it as shown in Fig. 52, and slide it up to the top edge of the paper, swinging the paper upon the pin already put in until it coincides with the upper edge of the T-square ; then put a second pin in the

bottom right-hand corner, and afterwards in the two remaining corners.

The pencil should be used solely at first for practising, and the most expensive drawing pencils are often the most economical to use in the drawing office. There are many well-known makes that may be depended upon to work smoothly and evenly without grittiness or inequality of texture. The number of H's marked upon the pencil indicate its relative hardness. For general use those marked H or HH will be suitable, while for particularly fine work HHHHHH may be necessary. For roughly sketching details on a large scale, a very soft lead, such as B will be found pleasantest to work with. Pencils of unvarnished cedar are to be preferred, and those of a

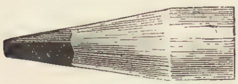


Fig. 53.—Chisel Shaped Pencil Point.

Fig. 54.—Round Point to Pencil.

hexagonal section do not roll off the sloping surface of the drawing-board or desk.

In sharpening the pencil a chisel point (Fig. 53), not a round point (Fig. 54), should be produced. Almost the first lesson for a draughtsman is how to properly sharpen a pencil, which is not easy for the beginner to accomplish satisfactorily. A pencil point should be well sharpened so that when the pencil is passing along the edge of a square it should be closely against it; and in ordinary drawing or tracing, a clear view should be obtained completely around it on the paper.

A round point wears away very rapidly, and will hardly make even one fine line, whereas if the edge be kept the full thickness of the lead in the direction of the line the pencil will last very much longer and produce better work; the flat faces of the lead point may be slightly rounded, as shown by Fig. 53.

If properly sharpened, one operation of the knife on the wood will be sufficient to allow of several re-sharpenings of the lead, whilst a badly sharpened point requires further hacking of the wood every time the lead is slightly worn.

Fig. 55 shows the T-square and pencil with the two hands in position for drawing an ordinary horizontal line. The pencil

should be upright when looking in the lengthways direction of the line, and sloping about five degrees from the upright in the direction in which it is being drawn, as would be seen at right angles to the line.

Now from each edge of the paper mark off $\frac{3}{4}$ in. and draw a border line all round, with plain square corners. The three

Fig. 55.—Method of Holding Pencil.

fingers at the back of the stock of the T-square keep it close to the edge of the board, which is not easy to do at first starting, but with a little patience and perseverance every border line can be drawn with equal facility. It is important to note that all pencil lines upon a drawing should be thin; if made thick they cannot be inked over so neatly, and the paper will have a greasy

Fig. 56.—Line in Error.

Fig. 57.—Dotted Line.

feel to the pen. The indiarubber should be used very sparingly, and if possible only after a drawing is completely inked in.

A pencil line drawn in error should have a wavy mark across it (as in Fig. 56), and one drawn full, but intended to be inked in dotted, should be marked as in Fig. 57 : this is instead of rubbing them out at the time. Another fundamental principle is always to draw a line far enough at the first attempt, but not to draw it beyond the distance it is known to be wanted. An unnecessary line takes time to draw, wastes the pencil point, and takes time to rub out; all matters of moment when excellence is in view.

The draughtsman will, at the onset, find it interesting and useful to test some of the instruments as to their essential qualities. For instance, a straightedge to be of use must be truly straight; the working edge of a T-square is a straightedge, and this may be tested by drawing with a fine chisel-shaped pencil-point a line as long as possible against the working edge of the T-square; then turn the blade over, and, setting the ends carefully to the line just drawn, draw another line against the

same edge adjacent to the line previously drawn. The principle of this test is shown in Fig. 58, where it will be seen that any irregularity in the edge is doubled in magnitude by the pencil lines. If the lines coincide exactly throughout their length, the edge is true; if they do not, the edge must be trued with a

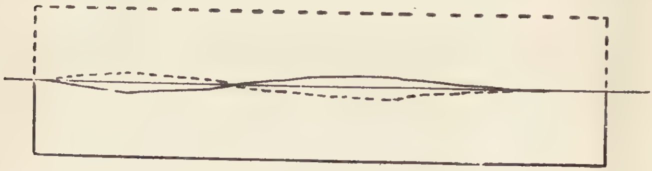


Fig. 58.—Testing Straight-edge.

fine-set plane, or glasspaper wrapped round a flat piece of wood.

The stock of the square should be exactly at right angles with the blade, but, as usually constructed, this is rather difficult to test without some true instrument of reference; and, paradoxical as it may seem, it does not matter if the stock is not exactly at

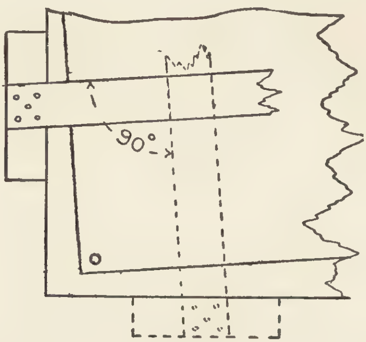


Fig. 59.—Untrue T-square makes Correct Angles.

right angles, as will be seen by Fig. 59, where, of course, the divergency is greatly exaggerated. In fact, the squareness of the T-square is entirely unessential for any work, but the absolute squareness of the board is most important. It will be observed that if the paper be set by the T-square, all lines drawn upon it

by an untrue square will still be parallel and perpendicular, so that a true drawing will be produced. If, however, the board be not square, a true T-square will not enable a square drawing to be made, as will be seen by Fig. 60, where the T-square is correct but the drawing-board is not square, causing the intended horizontal and vertical lines drawn upon it to have an angular error the same as the board.

The set-squares may next be tested. The end-grain edge and the long edge may be tested and trued up in the same way as the edge of the T-square blade; then, to test the right angle or square

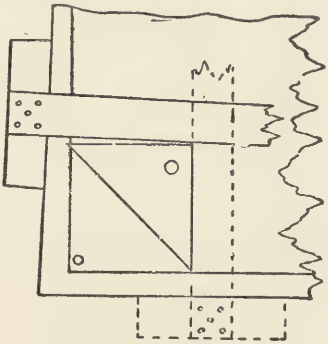


Fig. 60.—Untrue Board makes Incorrect Angles.

corner, hold the T-square firmly on the board, as shown in Fig. 61, and with the set-square against the top edge draw lines *a b*, *a c*, which will coincide if the squares are true, or may show any of the errors depicted in Fig. 61. This edge should then be trued up until the lines drawn upon reversing the set-square truly coincide. To straighten the edges of a set-square, lay a sheet of fine glasspaper on a level surface, place a wood block B with a square edge (see Fig. 62) on the paper, put the square S against the block, and rub the edge on the glasspaper until the angles are correct and the edges straight. The edges when very faulty may be planed with an iron smoothing-plane, and afterwards finished with glasspaper as described above. It is well to note that large set-squares produce better work than small ones, although the latter are more often used on account of their portability.

Now to test the drawing-board, and more particularly the working edges, which are the left-hand and bottom edges. There is one point in making a drawing-board that the inexperienced sometimes lose sight of, and that is the necessity of making the board perfectly rectangular. If this be done, the T-square may be shifted from one edge to an adjacent one, and lines drawn from the new position of the square will be at right angles to those drawn from the first position, although, as just explained, the T-square may be very far from square itself. First try the trued edge of the T-square along the edges of the board to see that they are neither hollow nor rounding, then rule a vertical line from the bottom edge, and, placing the T-square horizontal,

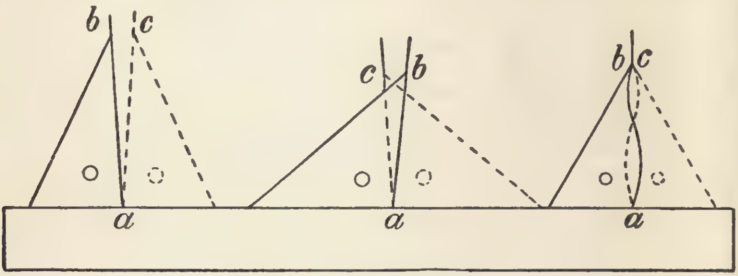


Fig. 61.—Testing Set-square.

draw a vertical line by means of the set-square, which should coincide with the vertical line previously drawn by the T-square; if it does not, the lower edge of the board should be shot, that is, planed true, afresh, and tried until the test shows no error. The board, T-square, and set-squares may now be considered to be in good working order and ready for use.

Before leaving this part of the subject, it may be useful to point out how parallel and perpendicular lines may be drawn when they are not in the same direction as the edges of the board. Fig. 63 shows the ordinary method used by draughtsmen; one set-square being laid down on the paper, the other is placed against it so that its long edge slides against the long edge of the former, and the two free edges give parallel and perpendicular lines as required. The carpenter and joiner may do this more readily with a stiff-jointed 2-ft. rule, using the drawing-board and T-square as shown in Fig. 64.

The testing and adjusting of the drawing-board, T-square, and set-squares having been satisfactorily accomplished, the draughtsman may now test and adjust himself so that he may be able to do his own personal work with the same relative precision.

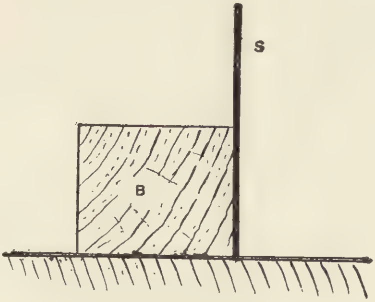


Fig. 62.—Straightening the Edge of a Set-square.

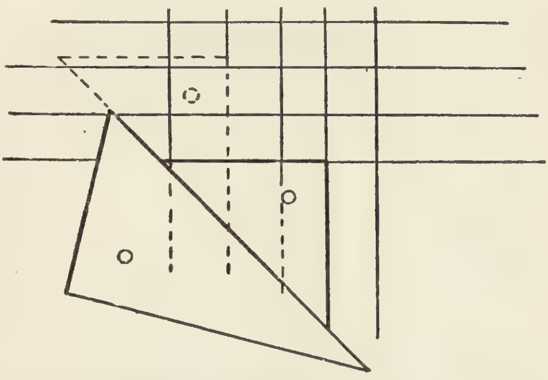


Fig. 63.—Drawing Parallel and Perpendicular Lines by Set-squares.

Draw upon the paper a firm T, as in Fig. 65, each of the two lines being exactly 2 in. long. Now study it attentively from a distance; at first the vertical stroke will seem much longer than the horizontal one, but by comparing the parts carefully it will be seen that the first impression was not a true one. Now, with one edge of a set-square, draw a straight line as nearly horizontal

as can be judged by the eye only, and 2 in. long. Mark what is judged to be the centre of its length, and then draw another line

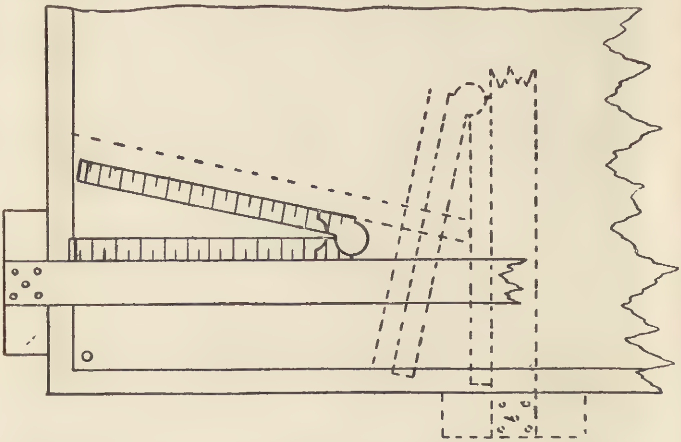


Fig. 64.—Drawing Parallel and Perpendicular Lines with T-square and 2-ft. Rule.

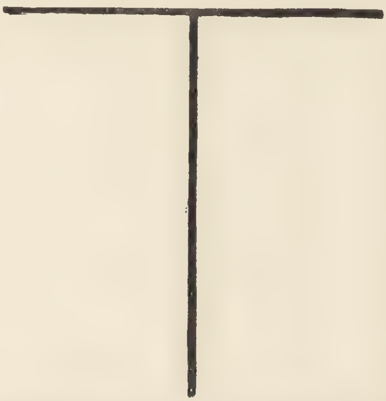


Fig. 65.—Equal Horizontal and Vertical Lines Appear Unequal.

of the same length at what is estimated to be a right angle from it. Test all these points by T-square and measurement, and

practise similar examples of judging lengths, central points, and angles, till the judgment will bear the test of measurement.

In the next example, Fig. 66, it requires some little practice to detect the true relative position of the three white spots, as the eye is easily deceived. In the drawing the white dots are

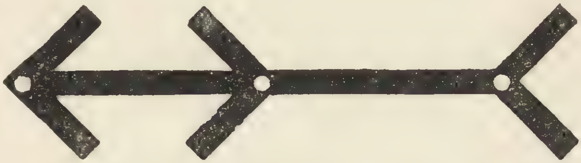


Fig. 66.—Equal Spaced Spots Appear Unequal.

uniformly spaced, but, to most people, the distance on the right-hand space looks much longer than that on the left, solely by reason of the lines drawn angleways confusing the judgment. Again, in Fig. 67, the two inner horizontal lines crossing the inclined ones are exactly straight and parallel with each other, but to many persons they look curved and wider apart in the

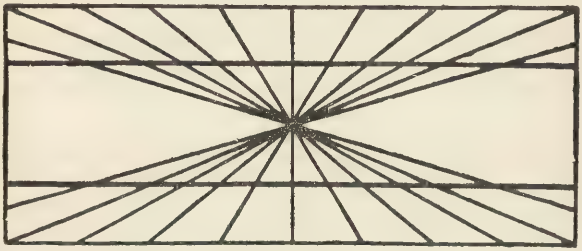


Fig. 67.—Two Parallel Straight Lines Appear Curved.

centre. This same principle is shown more strikingly in Fig. 68, where the vertical lines are all truly parallel, although they look to be alternately converging and diverging.

In Fig. 69 a true square is first drawn, and when part of the lower half is covered, it looks as if much more than the covered part is missing. In Figs. 70 and 71 the two circles are precisely the same size, but the black on a white ground looks smaller than the white on a black ground. This appearance is caused

because the white surface reflects the light, while the dark surface absorbs it.

A curious test for the eyesight is shown by Fig. 72, which consists of two black dots, about $\frac{1}{4}$ in. diameter, printed upon the

Fig. 68.—Parallel Lines Appear to Converge and to Diverge.

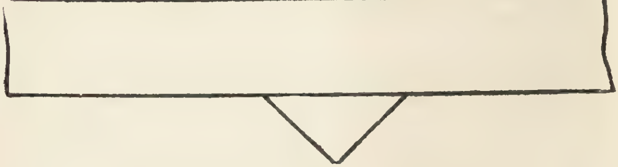


Fig. 69.—Square Partly Covered.

paper at a distance of 3 in. centre to centre. Shut the right eye, and, with the left eye, look at the right-hand dot; on moving the paper nearer or farther there will be found one position, when the eye is about 9 in. from the paper, at which the left-hand dot vanishes; at all other positions both dots can be seen at the

same time, although the eye is directed to the right-hand one only. This is owing to a small part of the retina of the eye having no power of vision, called the "blind spot," and it is why sometimes, the head being held in a certain position, a dimension figure will disappear from a drawing. On the other

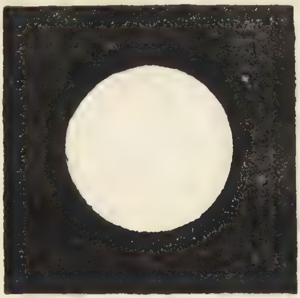


Fig. 70.

Fig. 71.

Figs. 70 and 71.—Circles of Equal Size Appear Unequal.

hand, the eyes can sometimes see more than one would expect, as when a stereoscopic view is held in the hand and gradually brought into position until the two pictures appear superposed, when the vista of true perspective will give an air of solidity to the view equal to any stereoscope. Composite photographs may be optically produced in this way from two separate cards of

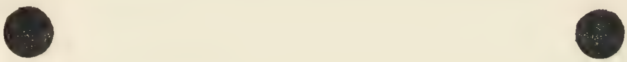


Fig. 72.—Disappearing Dot Illustrating Blind Spot in the Eye.

persons, showing the heads about the same size and position. Not only upon the drawing-board and in the workshop should the eye be educated ; the same kind of practice should be kept up out-of-doors and in the workshop.

The set of examples illustrated by Figs. 73 to 75 may be tried over again when the lines are closer together, when any irregularities will be found to show much more clearly. If the

lines are placed less than $\frac{1}{16}$ in. apart, they will appear, at a little distance, like an even tint of shading, and the closer they are the more difficult will it be to get the appearance quite uniform, but this is very good practice.

The following examples (Figs. 73 to 75) are selected out of a large number of possible combinations, as giving variety of practice while not appearing too difficult. They are, however, more difficult than they appear, so that they must be commenced with the determination to produce very neat and accurate drawings.

After drawing the border line in pencil, $\frac{3}{4}$ in. from each edge

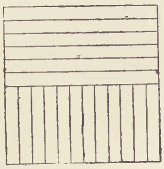


Fig. 73.

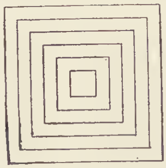


Fig. 74.

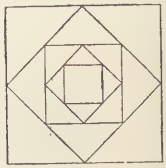


Fig. 75.

Figs. 73 to 75.—Square Figures for Practice in Drawing.

of the paper, as already described, find by measurement the centre of the paper, so that the second square (Fig. 74) may be placed in the middle, rule a horizontal line for the squares to rest upon, draw the middle one in outline first, and then the others, each measuring 3 in. along one side. The spaces between the border line and each of the squares should be equal. In the upper half of the first square (Fig. 73) mark off equal divisions of $\frac{1}{4}$ in. each, and draw horizontal lines; then, in the lower half, mark off similar distances and draw vertical lines. In the second square (Fig. 74) equal distances must be set off from each of the sides, and parallel lines drawn, so as to make a number of complete squares. These should be drawn with a fine chisel-pointed pencil, and then tested by drawing diagonal lines from opposite corners. If the squares have been correctly set out, all the angles will be upon one or other of the diagonal lines. In the third square (Fig. 75) the inner squares are drawn with their angles tangent to the sides of the one next larger. If very fine pencil lines are drawn across opposite angles of the outer square, and then two other lines bisecting the sides, it will be found easy to join up the inner squares to the points so found.

The next lesson illustrates the method of drawing and inking lines. A border line may be pencilled round the paper $\frac{3}{4}$ in. from each edge; then rule horizontal lines, the top one being about 2 in. below the top border line. About 1 in. below, mark the position for the upper full line, and from this mark off five more positions each $\frac{1}{2}$ in. distant from that above it.

Fig. 76.—Full Lines.

Then, through the two first positions, draw full lines (Fig. 76), 9 in. long and with each end equidistant from the border. Through the ends draw faint lines vertically downward, and then draw the dotted lines (Fig. 77) and dimension lines (Fig. 78), their lengths being limited by the faint lines just mentioned. Dotted lines, as shown in Fig. 77, are used to represent hidden edges of surfaces; they are sometimes called broken lines, and

Fig. 77.—Dotted Lines.

consist of alternate short strokes and spaces measuring about $\frac{1}{16}$ in. each. Dimension lines, as shown in Fig. 78, consist of open dotted lines. These dimension lines are to guide the eye from arrow-head to arrow-head in reading dimensions, as shown in Fig. 79; they should consist of strokes not more than $\frac{1}{16}$ in. long, and not less than $\frac{1}{4}$ in. apart; in long dimension lines the strokes may be $\frac{1}{2}$ in. apart. It will be worth while to measure these

Fig. 78.—Dimension Lines.

distances the first time of drawing them, but a very little practice should enable a draughtsman to judge of the correct length without actual measurement. When making finished drawings, in practice it is found best, when inking in, to use straight blue ink lines terminated at the ends by black arrow-heads.

When it is desired to show the interior construction of any object, an imaginary cut is made through it, and the representa-

tion of the cut surface is called a section. The direction of the cut is marked upon the original drawing by a line of section, formed of strokes and dots placed alternately, with a letter at each end, as A B upon Fig. 80. This line is usually in red ink,

Fig. 79.—Method of Showing Dimensions.

but as all the work in the present lessons is black and white this dotted section line may be made the same as the other lines. The horizontal graduated lines in Fig. 81 are meant to be of different thicknesses; this is done when inking-in; for the present simply draw five thin pencil lines ½ in. apart.

Fig. 80.—Line of Section.

Before beginning to ink-in the figures that have been pencilled, see that the drawing-pen is clean. Never let the ink dry between the nibs, but wipe the drawing-pens with a piece of soft rag after using. In inking-in always try to improve upon the pencilling, get an exact fit at all angles, and let tangent parts just touch—neither more nor less.

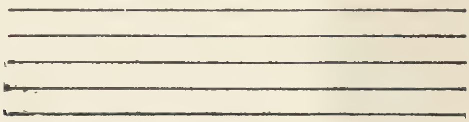


Fig. 81.—Graduated Lines.

The next process is to ink-in the straight lines. Take the drawing-pen (Fig. 19, p. 24), open it about a sixteenth of an inch, then close it by the screw until daylight just shows between the nibs; now hold it in the lips, and breathe between the nibs, then dip them carefully into the Indian-ink bottle so as just to touch the surface of the liquid, when the ink will run up between the nibs, following the moisture deposited by the breath without wetting the outside of the pen. Try on a separate piece of paper for the right thickness of line. A piece of chamois leather or rag should be

kept handy to wipe the outsides of the nibs in case of ink being there, because if ink be allowed to get on the outside of the pen, a blotted line will be the consequence.

Now hold the drawing-pen as shown in Fig. 82 and carefully ink-in all the horizontal lines, both full and dotted, correcting, if possible, any slight irregularities that may have been made in pencilling. In drawing the graduated lines

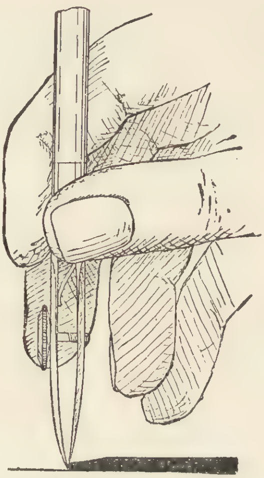


Fig. 82.—How to Hold a Ruling Pen.

Fig. 81), begin with the thinnest, then with the middle finger, as shown in Fig. 82, turn the screw of the pen back, say, about a quarter of a revolution for each of the others, the last opening being about the right thickness for the border line. As the border line takes longer to dry it is very easy to smear, but of course this may be avoided by letting the ink dry while preparing the ink-leg for the compasses.

CHAPTER IV.

DRAWING CIRCULAR LINES.

COMPASS curves is the name given to all curves composed of circular arcs. They can be drawn by the compasses in one or more operations, and the name distinguishes them from lines of varying curvature, which are again divided into various classes according to their character. With compasses in hand, the con-

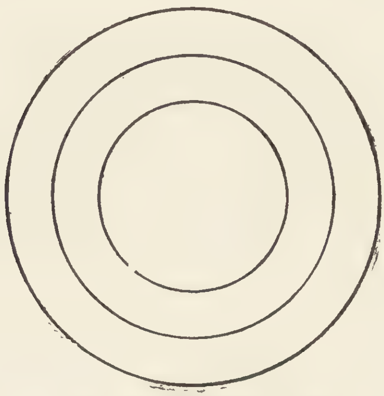


Fig. 83.—Concentric Circles.

struction of a circle is so simple that anyone can strike a circle of some sort; but many persons who think they are draughtsmen cannot draw a good circle. Strike, describe, and draw are three terms used indifferently for the operation of *making* a circle.

To ensure good work: Hold the compasses by the top joint; place the pencil or pen perpendicular to the paper and, sloping it slightly in the direction of motion, make the circle by one sweep of the compass. Now try to make three concentric circles, as shown at Fig. 83, on the paper by these rules, remembering

that concentric circles are those having the same centre, and proceeding as follows :—

As when drawing straight lines, first commence with a border line, three-quarters of an inch from the edge all round the paper, then draw vertical and horizontal centre lines, so that their intersection will show the point where the point of the compasses is to be placed. Open the compasses to 2 in., measured on one of the scales, and strike the outer circle. Then partially close the compasses to $1\frac{1}{2}$ in. on the scale, using only the right hand for the compasses and the left to steady the scale, and describe the second circle. Then close further to 1 in. and draw

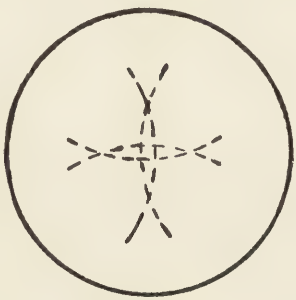


Fig. 84.—Finding Centre of Circle.

the inner circle. The illustrations printed in this book are half the size they are to be drawn.

The difficulty of estimating the point that is exactly the centre of a circle may be tested by taking a penny and marking the outline of a circle with it on the paper ; then mark where the centre is estimated to be, and afterwards test it by drawing short arcs from four opposite points by the compasses, as in Fig. 84. Following this, a useful practice would be to sketch a circle freehand and test it by finding the mean centre, and then striking a true circle by the compasses.

As a further lesson, the interesting work of drawing curves may be taken. The curves across the lower part of the diagram (Fig. 85, p. 54) are known as flat curves, because, having a large radius, they have not very much "bend" in them. To draw these, first put in a thin centre line down the paper, then mark the positions

where the curves cross the centre line $\frac{1}{2}$ in. apart, and from the inner one measure 6 in. to point (Fig. 85), which is to be used as the centre. Open the compasses wide enough to make the largest curve first; see that the point of the compass pencil is chisel-shaped, as shown in Fig. 53, p. 38, and in the right direction to make a thin line; if the compass leg has a joint, bend it so that

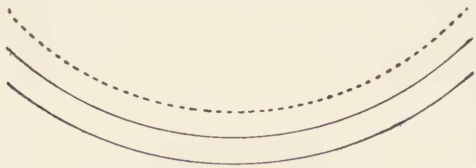


Fig. 85.—Flat Curves.

the pencil is at right angles to the paper, and then, holding the compasses by the top, as in Fig. 86, swing them round carefully to make the curve the required length. Do the same with the other two curves in Fig. 85, putting the dotted one in as a full

Fig. 86.—Holding Compasses.

Fig. 87.—Sharp Curves.

line, and making a few short strokes across it, as shown in Fig. 57, p. 39, to indicate that it must be dotted when inking-in, as described on p. 39.

Large or flat curves are really more difficult to draw than small ones, although many think the contrary, but the fact is that any irregularity shows more in a small curve. Now very carefully mark the centre (Fig. 87), and measure off $\frac{1}{2}$ in. distances along a thin horizontal line through which the small curves will be drawn, the largest of them being 3 in. radius. This completes the pencilling; but, to ensure neat work in inking, see that the terminations of all the lines and curves are clearly indicated,

either by a thin pencil line drawn across their ends, or by being drawn very neatly and terminated evenly.

Next try some pieces of circles, or arcs, as they are called. Let them be concentric, as shown at Fig. 88, with radii of 3 in., $3\frac{1}{2}$ in. and 4 in., and each 4 in. long, measuring from end to end

Fig. 88.—Concentric Arcs.

in a straight line, that is, measuring the chord of the arc instead of the arc itself. These might be called parallel curves, and, although this is an expressive term and not likely to be misunderstood, they are not a correct example of parallelism.

Now try three more arcs, but all struck with the same radius,

Fig. 89.—Arcs of Equal Radius.

as at Fig. 89, say 3 in., and the same distance apart on the centre line, say $\frac{1}{2}$ in. These curves are exact counterparts of each other, although they look much less regular than the concentric arcs, and an important principle is involved in the comparison.

To find the centre of any small compass curve as A B, Fig. 90, p. 56, from points A and B strike arcs of the same radius intersecting at *c* and *d*, and draw a line through the intersections cutting the arc at *e*. This line will pass through the centre. Then from points *e* and B, with a rather smaller radius, strike arcs intersecting at *f* and *g*; draw a line through these intersections, and

where it cuts the previous line will be the required centre, as shown at *h*.

Before drawing the circles (Figs. 91 to 93), a pair of centre

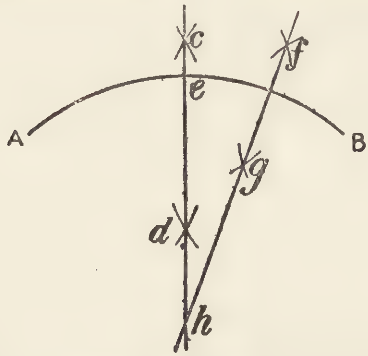


Fig. 90.—To Find the Centre of a Small Arc.

lines cutting each other at right angles must be drawn for each, and it should be a stringent rule never to draw a circle under any circumstances without first having two centre lines to mark its position. In the first circle (Fig. 91), mark off points $\frac{1}{4}$ in. apart

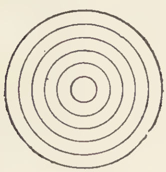


Fig. 91.

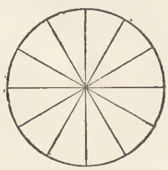


Fig. 92.

Fig. 93.

Figs. 91 to 93.—Circles for Practice.

along one of the diameters from the circumference to the centre, and then describe the concentric circles with the compasses, taking care not to bore a large hole through the paper with the point. The compasses, if properly sharpened, should barely penetrate the paper and leave no impression on the board.

To fill up the middle circle (Fig. 92), set the compasses to the radius, and then, putting the point at the intersection of one of

the centre lines with the circumference, mark across the circumference on each side ; do the same at each intersection of the centre line with circumference, and it will be found that the circumference is then divided into twelve equal parts. Now join each opposite joint by a line passing through the centre and the figure will be complete.

The last figure to be drawn (Fig. 93, p. 56) is the most difficult, but has the best effect, so it is worth taking some pains over. Draw the two centre lines, put in the large circle, and divide the horizontal diameter into $\frac{1}{4}$ in. spaces. Take the bow-pencil (Fig. 38, p. 31) or small compass (Fig. 36, p. 31), set it to $\frac{1}{4}$ in. radius, and then put in

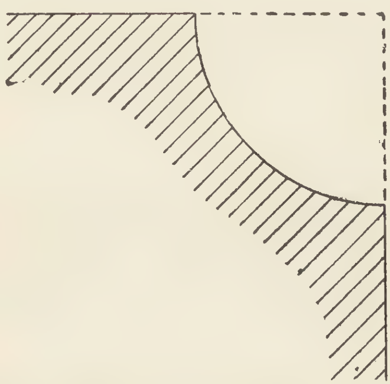


Fig. 94.—Old-fashioned Hollow Edge of Castings.

the smallest semicircle on each side. Then set it to $\frac{1}{2}$ in. radius, and put in the next semicircle ; then to $\frac{3}{4}$ in. radius for the next two semicircles, which should exactly meet at the centre. Now to 1 in. radius, and, lastly, to $1\frac{1}{4}$ in. radius, checking the curves before actually drawing them, by seeing how they fit with those already drawn.

Curves applied to machinery and buildings, as a rule are introduced with an object in view. A favourite method of finishing the edges of castings, until about thirty years ago, was to run a hollow curve along them as in the illustration, Fig. 94. This is very easily drawn by opening the compasses to the required radius and placing the point at the junction of the two

straight lines, as seen in the section. When engineers began to consider the why and the wherefore, and to see beauty only in that which was strictly adapted to strength or economy, they saw that this curve was even worse than a plain angle, for it gives two sharp edges to damage and be damaged, and a groove to hold the dirt.

A rounded angle (Fig. 95), whether internal or external, was found to produce a better arrangement of the crystallisation of the iron in cooling, it gave a stronger casting, was less liable to damage, and altogether more appropriate. This is perhaps

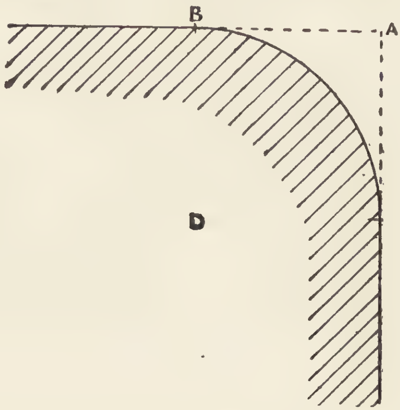


Fig. 95.—Modern Angle of Castings Internal and External.

the most important curve a beginner can have; though difficult to draw well if the centre has to be guessed at, it presents no difficulty and takes less time if the right method be followed. First decide upon the radius, say 2 in.; set the compasses to this, place the point at the intersection of the straight lines A, and mark with the compasses across each of the lines B and C. Then from the intersections of each of these marks, draw intersecting arcs within the lines to give the exact place, marked D, for the point of the compasses to draw the rounded angle. If care be taken it will be found that the curve exactly fits the straight lines, which is of course what the draughtsman should aim at.

A more advanced example, such as would occur in fitting a curve between the arm and boss of wheel, is shown at Fig. 96

Let a be the centre of the wheel, $a\,b$ the radius of the boss, say 3 in., and $b\,c\,d$ part of the boss; also let $d\,e$ be part of the arm. It is required to join them by a curve of $1\frac{1}{2}$ in. radius. Open the compasses $1\frac{1}{2}$ in., and from two points on the curve, and two on

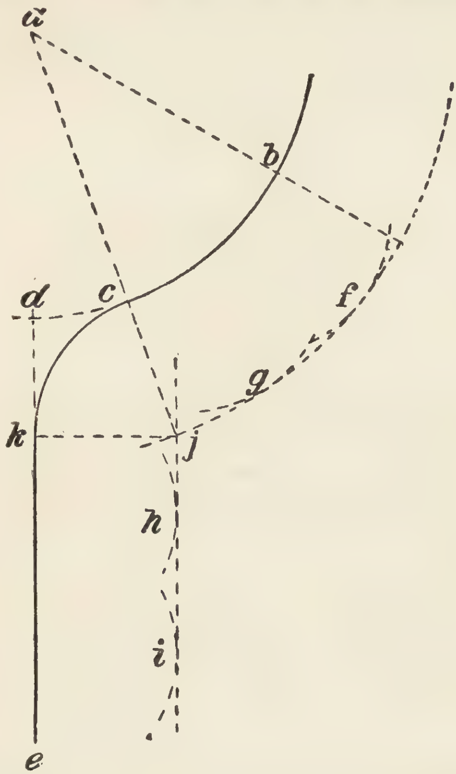


Fig. 96.—Curves Joining Arms and Boss of Wheel.

the straight line, draw short arcs as shown at $f\,g$, $h\,i$. Then draw a straight line tangent to the two arcs from the line, and with the compasses a concentric arc tangent to the two small arcs from the curve. Where this new line and curve cross each other (j) will be the exact centre for the curve of $1\frac{1}{2}$ in. radius to

join the arm and the boss. It is important to note that the exact point of meeting of the two curves will be at *c* in the line *aj*, joining their centres; and of the curve and straight line at *k*, where a perpendicular would fall from *j*.

The illustrations given in Figs. 94 to 96, pp. 57—59, show the application of the simplest elements of practical geometry to the production of good junctions in the outlines of a drawing.

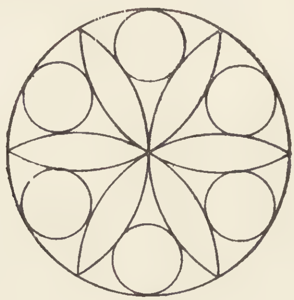


Fig. 97.—Example Requiring Accurate Drawing.

The study of practical geometry forms a very good groundwork for a draughtsman, and in machine drawing is quite indispensable; but for architectural drawing there is a great deal that may be omitted. One of the advantages pertaining to it is that it compels neat work, as the problems will not work out unless accurately set off.

The illustration shown at Fig. 97 is left without any explanation; it will be found interesting to work out, and it will also be a good example for showing accurate draughtsmanship.

Fig. 95, p. 58, shows how a square angle is rounded off with a given radius. After considerable practice the draughtsman can often guess the position of the centre of the curve fairly accurately, but instead of prodding about to find a centre which will permit the curve to meet the straight lines, it is better to use the geometrical method, which is as follows: Produce the two lines till they meet at A as shown dotted; then, with the meeting point A as centre and a radius equal to the radius of the required curve, cut each of the two lines at B and C, and, from each of these two points as centres, strike arcs that cut one another at D, which is the required centre.

The tangent curve can then be drawn accurately and easily. With a little practice, this method is so much more rapid and exact than guessing at the centre that there is good reason for adopting it always. Fig. 94, p. 57, is the opposite of Fig. 95, and is too simple to need explanation.

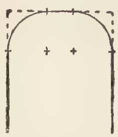


Fig. 98.—Rounded Corners.

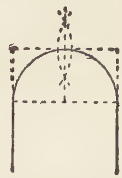


Fig. 99.—Parallel Lines joined by a Semicircle.

Fig. 98 shows the method just described applied to three straight lines forming two right angles and having two adjacent corners rounded.

Fig. 99 shows how to deal with two parallel lines that are to be joined tangentially by a semicircle. In this case bisect the space between the two lines by a perpendicular line that must contain the centre of the circle from which the required curve is

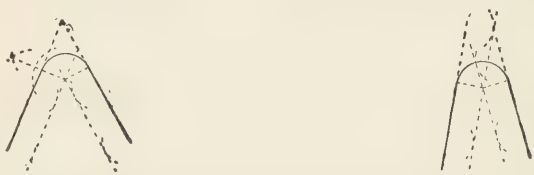


Fig. 100.—Angular Lines Joined by Circular Arcs.

formed. Determine the extreme position of the curve and mark from it, along the centre line, a distance equal to half the distance between the lines, and this mark will be the centre of the required circle.

Fig. 100 is more difficult, as in this figure the lines, which it is desired to join by a curve, are not at right angles. Therefore, inside these, and at a distance from them equal to the radius of the curve which it is desired to use, draw two parallel lines. To

do this, take the radius in the compasses and strike two arcs at some distance apart along the inside of each line. Tangent to these draw the two inner straight lines shown dotted, and their intersection will give the centre required. The exact points of junction of the straight lines with the curve can be found by drawing perpendiculars from the centre to the straight lines by the method shown on the left-hand side of Fig. 100.

The figure on the left side is exactly similar to the last, with the exception that it represents a sharper angle than that shown by the angle or corner in the right hand figure.

Fig. 101 shows the junction of a straight line and curve by a

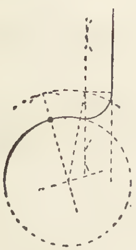


Fig. 101.

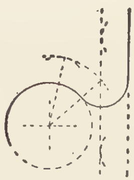


Fig. 102.

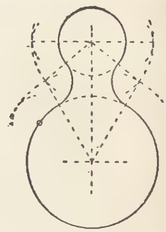


Fig. 103.

Figs. 101 to 103.—Examples of Curved Lines as Junctions.

smaller curve. In this example, after drawing the given straight line and circle, set the compasses to the required radius, and from any point on the circumference of the circle describe a short arc outside it. From the centre of the circle draw a straight line through this last point, and its intersection with the arc will give the radius of an arc concentric with the large circle which must be drawn towards the given line. Then, with the required radius, again set off arcs from the given line to give a parallel line, as in Figs. 99 and 100. The intersection of this parallel line with the larger arc will give the centre to use for the connecting curve. In every case it will be observed that the perpendicular line from the centre of the junction curve to the line, or the line joining the centres of the two curves, will give the exact termination of the junction curve.

Fig. 102 is practically the same as Fig. 101, with different radii.

Fig. 103 shows two circles of different size joined by two

curves of equal radii, set off upon the same principle as Figs. 101 and 102.

Fig. 104 shows a straight line cutting a circle and joined by small curves on the inside. After drawing the circle and straight line, take the required radius of connecting curve and draw a short arc on the inside of large curve—say, on the centre line—and from the main centre draw an arc concentric with the large circle, but inside it. Then, with the required radius, obtain a line parallel to the given line, and the intersections of this parallel line with the large arc will give the centres for the connecting curves.

Fig. 105 shows two given parallel straight lines which are to be

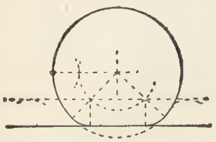


Fig. 104.—Curved Joins.

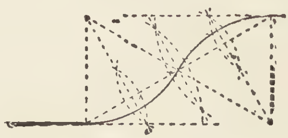


Fig. 105.—Ogee Curve.

joined by an ogee or reversed curve. Select a point on one of the lines from which the curves may start, draw a horizontal line and also an inclined line, making an angle of 60° with it. The latter line produced to cut the other given straight line will mark the termination of the curves. Bisect this inclined line, and it will give the junction point between the two curves. Bisect each half of the inclined line and produce the bisection to meet the horizontal lines, to give the centres for the curves. Before drawing the curves, join these centres, to see that a straight line will pass exactly through the junction of the two curves, and then put in the curves with a radius equal to half the length of inclined line. This is a very useful curve, and is similar to those used for cross-over roads on railways. In architecture the best curves are produced from conic sections or freehand Circular curves have a harsh appearance. There are, nevertheless, many cases where they are necessary or desirable.

The remaining examples in this chapter (Figs. 106 to 113) are all well-known mouldings, whose beauty consists in their simplicity. Many beginners will appreciate the ability to make, at this early stage, drawings that soon look architectural. There

are many cases where mouldings are intended purely for ornament, as round the panels of a door; but there are other cases where the mouldings form a definite addition to the strength, as at the ends of a cast-iron column.

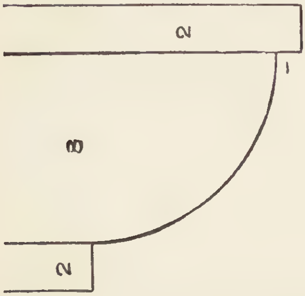


Fig. 106.—Ovolo or Quarter-round Moulding.

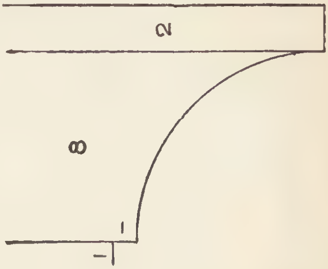


Fig. 107.—Cavetto or Hollow.

Speaking broadly, mouldings may be divided into two classes, known as Roman and Grecian, the former being compass curves and the latter derived from the conic sections. They are used

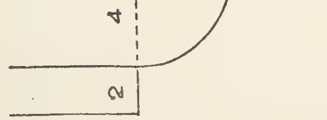


Fig. 108.—Cyma Recta or Ogee.

Fig. 109.—Cyma Reversa—Reversed Ogee.

generally for relieving straight lines by giving variety of shade, or for lessening the abruptness of the junctions of various parts.

In the examples shown at Figs. 106 to 113 a quarter of an inch is taken as the unit, the figures marked on the illustration giving the number of quarter-inches in each piece. These must not be

taken as fixed proportions, but merely as suitable sizes for the examples. It will be seen that every curve forms exactly a quarter of a circle, and very neat junctions should be made where

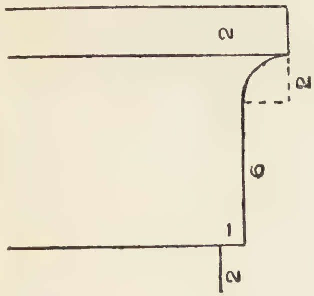


Fig. 110.—Scape Moulding.

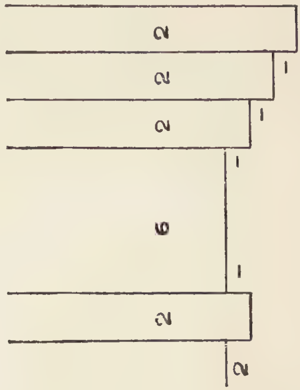


Fig. 111.—Fillets or Annulets.

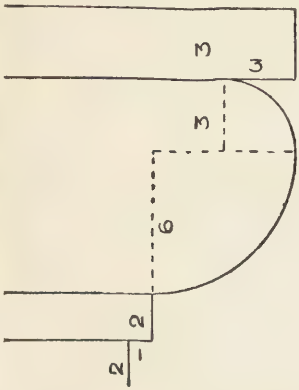


Fig. 112.—Quirked Ovolo.

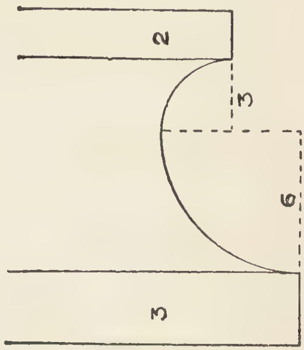


Fig. 113.—Scotia.

two curves meet. The dotted lines show that tangent curves always meet upon the line joining their centres.

The heading to this drawing should be in block letters $\frac{5}{16}$ in. deep, and the descriptions in block letters $\frac{1}{8}$ in. deep, all upright.

It is better to avoid ornamental printing at least until some facility has been attained in making plain block letters, as no other lettering can exceed this in clearness and neatness.

There are many other mouldings founded upon these or made up by a combination of two or more, and it will be interesting to examine a stock of mouldings or a pattern book of machine-made mouldings, to see how the sections are made up. Attempts to design a moulding should not be encouraged until a good general knowledge has been obtained of those in use. It is one thing to have a striking outline in section and quite another to see the same thing in elevation; there is much scope for taste in selecting

Fig. 114.—Semicircular Arch.

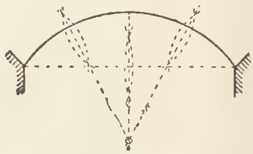


Fig. 115.—Segmental Arch.

an appropriate moulding for any purpose, as there is also in designing a piece of architectural work. The majority of mouldings made up of compass curves are ugly, but there are cases where they are appropriate, and that is the excuse for making them.

If buildings containing arches of various shapes be examined it will be found that although every arch is made up of a great number of lines for mouldings, etc., there is a type underlying each different arrangement. Outlines of the commoner forms of arches are shown in Figs. 114 to 121. The curves, of course, simply show the types, the construction of the arch being on the lines shown. In other words, every arch may be reduced to a single line, the shape of which indicates the type of arch, and is really the foundation of its construction. In connection with the arch there will always be the supports—either piers or abutments—which receive the weight and thrust. The true termination of the arch may sometimes be obscured, as in certain stone arches, and at other times perfectly evident, as in brick arches. The termination is the skewback, which should be always at right angles to the direction of the curve; or, when the curve is struck from centres, the skewback is radial from the centre used for the adjacent part of the curve. In the diagram given in the follow-

ing eight figures the skewbacks and abutments are indicated for each arch.

The first one (Fig. 114) is a semicircular arch of 3 ft. span—that is of 1 ft. 6 in. radius—and is a full half circle; in this the skewback is horizontal, and it is popularly supposed that on that account there is no thrust, but it is a misapprehension, as there is a thrust amounting approximately to one-fourth of the load. The semicircular arch occurs very largely in Norman architecture (A.D. 1066-1189), and also in Classical architecture.

The next case (Fig. 115) is a very common form, but properly a segment arch, often called a jack arch, or circular arch, or segmental arch. It is to have a span of 4 ft. and a rise of 1 ft., and

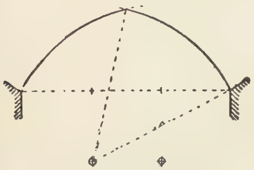


Fig. 116.—Segmental Arch.

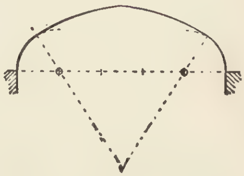


Fig. 117.—Tudor Arch.

the radius must be found by a geometrical construction, thus: Mark off the span upon a horizontal line representing the springing line, and from that, upon a vertical centre line, mark off the rise; three points will then be given through which the curve must pass. Take these points in pairs, and with any radius a little greater than half the distance between them draw intersecting arcs; through the points of intersection draw straight lines which will meet at a point giving the centre from which the arch curve is to be struck.

To set off a segmental arch (Fig. 116) divide the springing line into three equal parts, and upon the under side of the middle third construct a square, the lower corners of which will give the centres to be used. To set off the Tudor arch (Fig. 117) divide the springing line into five equal parts; take three of these parts, measured downwards under the central division, for the length of a rectangle, one division wide, whose lower corners will give the centres for the middle portion of the arch; the sides of the arch have a radius of one division. Draw lines through the centres to mark the junctions of the curves, and put in the

curves so that they do not show a joint. Figs. 116 and 117 are sometimes called flat-pointed arches, to distinguish them from the earlier lancet and equilateral arches (Figs. 119 and 120). In inking-in these examples let the construction lines be very thin and neat, and the outlines clear and bold. If any mouldings were shown to these arches they would be struck from the same centres, so as to give parallel curves.

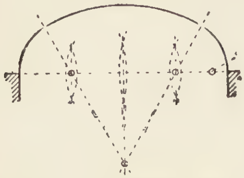


Fig. 118.—Elliptical Arch.

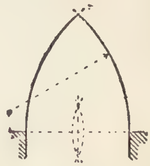


Fig. 119.—Lancet Arch.

A true elliptical arch cannot be struck from centres, as it is a conic section, but a very fair one may be set out as shown in Fig. 118. Divide the springing line into four equal parts, and upon the two middle ones construct an equilateral triangle ; then the corners of the triangle will give the centres for the different curves of which the arch is composed.

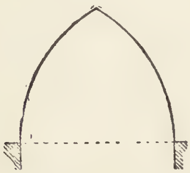


Fig. 120.—Equilateral Arch.

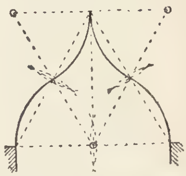


Fig. 121.—Ogee Arch.

The lancet arch (Fig. 119), so common in Early English architecture (A.D. 1189-1307), has the centres on the springing line, and the radius used is equal to one and a-half times the span. The equilateral arch (Fig. 120) is the easiest of all to draw, the radius being equal to the span. It was much used in the Geometrical Period, at the early part of the fourteenth century.

The next arch is drawn upon the same principles as the ogee curve shown in Fig. 121, and with the construction lines given requires no further explanation. It is defective as a scientific

arch, but occurs often in the Decorated Period, towards the end of the fourteenth century. After that period the arches were made flatter, examples of which are the segmental, or two-centred, and the Tudor, or four-centred, arches.

This ink-leg of the compasses works very similarly to the ruling pen that has been described in the previous chapter on p. 24, so that little further instruction is required. See that the nibs are square to the paper, hold the compasses by the joint

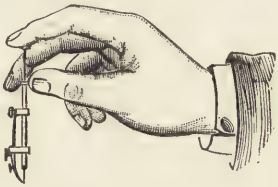


Fig. 122.—Method of using the Pump.

between the right thumb and fingers, and use the left hand only to steady the point at starting by resting the fingers on the paper. Never use two hands to the compasses. The smaller curves are not easy to put in with large compasses—a bow pen (Fig. 39, p. 31) or small compass (Fig. 36, p. 31) is generally used; and for a number of very small circles, such as rivet-heads, pump bows (Fig. 40, p. 32) have a great advantage, and the method of using this instrument is shown by Fig. 122. Lines for the small printing may now be ruled, and all the lettering put in neatly with a steel writing pen.

CHAPTER V.

ELLIPTICAL CURVES.

In the last chapter circular curves were dealt with, and by a very easy transition we pass to elliptical curves, or ellipses, commonly called ovals—although strictly an oval is larger one end than the other, like a hen's egg (Latin *ovum*, an egg). The ellipse occurs frequently in machine drawing and sometimes also in civil engineering and architecture.

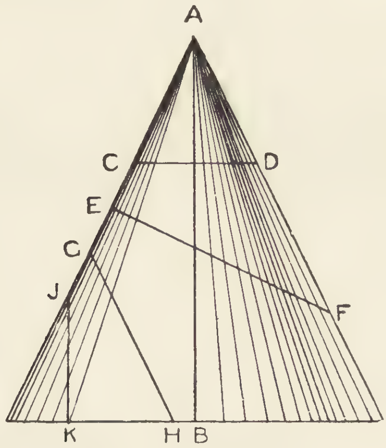


Fig. 123.—The Conic Sections. A B Triangle; C D Circle; E F Ellipse; G H Parabola; J K Hyperbola.

The principal curves are derived from conic sections, so it will be well now to study the different ways in which a cone may be cut in the way shown by Fig. 123. A vertical section passing through the apex of the cone, as A B, the cut surface will represent a plane triangle, and any horizontal section, as C D, will form a circle.

A section in any direction not horizontal, so long as it passes only through the sloping sides of the cone, as E F, will form an ellipse; if the section be nearly horizontal, the ellipse will be nearly a circle, and if it be nearly parallel with the slope, it will be long and narrow.

A section cutting anywhere through the base and parallel to the sloping surface, as G H, will form a parabola: while a vertical section, as J K, not passing through the apex will form a hyperbola. These two may be called open curves, because they do not form a closed figure, unless the straight base be taken as part of the figure. It will help to impress the derivation of the different curves on the mind if the cone be drawn and the lines of the section marked on it. The cone may also be shaded by lines as shown, observing that on the left the shading is narrow and

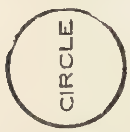


Fig. 124.

Fig. 125.

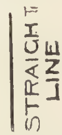


Fig. 126.

darkest at the outer edge, while on the right it is much broader, but darkest a little way off the edge and lighter towards each side, giving the effect of reflected light on the right-hand side.

Whenever a circle is viewed otherwise than at right angles to its plane it appears as an ellipse, though of course its real shape remains unaltered. Wheels, pulleys, drums, collars, couplings, and many other parts, act the same as the penny referred to in the last lesson, but they form as many ellipses as they have circles in their construction. Besides these, there are cases of actual ellipses, as in the elliptical holes cut for handholes in machine framings, elliptical gearing, elliptical arches, elliptical flower-beds, etc. A penny held up at arm's length towards a window will show different shapes according to its position. The full view will be a circle as Fig. 124, and then by turning it slowly the circle will become an ellipse, retaining the full depth but getting gradually less in width, as Fig. 125, and ultimately showing only a straight line, as Fig. 126. Every intermediate position that can be taken between Figs. 124 and 126 will give an ellipse, so that there is no fixed

proportion between the two diameters; thus an ellipse may be obtained of any required length and width.

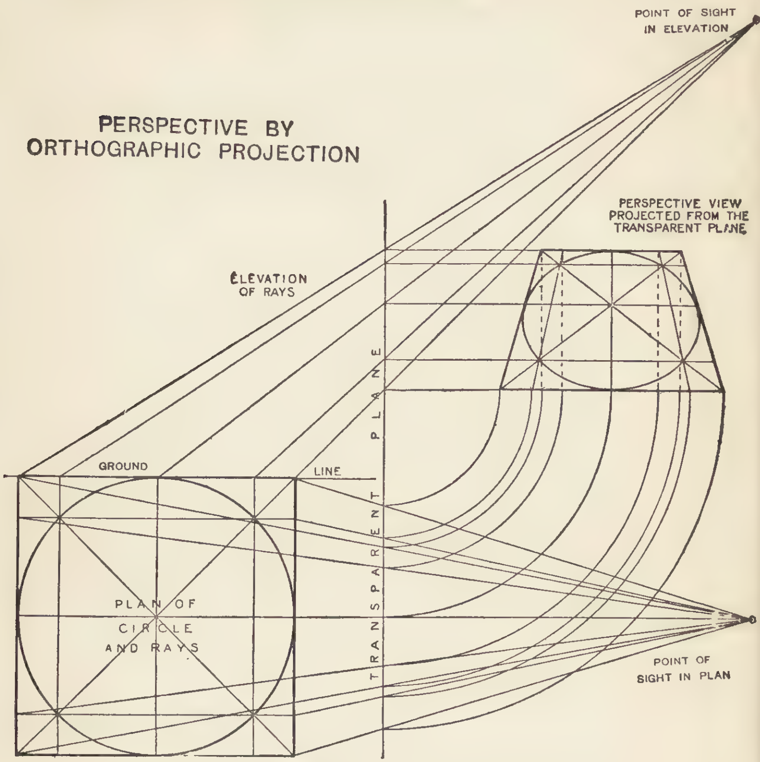


Fig. 127.—Ellipse Projected from a Circle.

It has been contended that, although the perspective view of a circle is something like an ellipse, it would quickly be detected as "out of drawing," but it will be found that the statement is correct. The centre lines of the circle will not remain the centre lines of the ellipse, and this is where the misunderstanding arises. Fig. 127 shows a circle in perspective, with the enclosing square, its diagonals, and centre lines. This will be found to be a true ellipse. This figure also shows in one view how perspective

representations may be derived from ordinary projection such as every draughtsman is in the habit of using, and gives an opportunity of testing whether a circle in perspective is a true ellipse.

In the lower left-hand corner a square is drawn and a circle inscribed ; the diagonals of the square are then drawn, and where they cut the circle other lines parallel with the sides are drawn. Parallel with two of the sides a line is drawn to represent the transparent plane or surface which is to receive the picture, and beyond this a point is selected to represent the position of spectator or point of sight. The top edge of the square is made coincident with the ground line for the elevation, and a height is assumed for

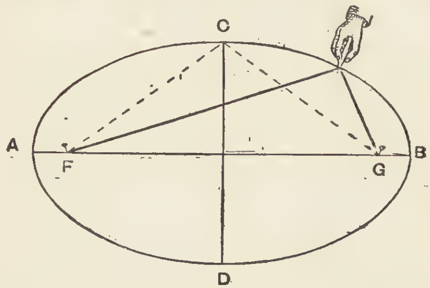


Fig. 128.—Simple Way to Draw a True Ellipse.

the spectator's eye directly over the point of sight in the plan. Lines or rays are then drawn from certain of the points on the boundary of the square to the points of sight, and where the elevation rays cut the transparent plane, horizontal lines are projected, and the lowest of these intersections is used as a centre round which to turn the horizontal intersections in a quadrant to give vertical lines cutting the previous horizontal ones. The perspective view of the square being thus obtained, a curve is drawn through the points so found to represent the circle in perspective, and, on testing this, it will be found to be a true ellipse, notwithstanding the fact that the back half of the circle appears so much smaller (because more distant) than the front half.

A simple way to draw a true ellipse is shown at Fig. 128. First draw the major and minor axes, as A B and C D respectively. Then from C or D as centre, with half the length of A B in the compasses, cut A B in the points F and G. These are the two foci.

Take a piece of string as long as G C+C F, and fasten the ends by pins at F and G. With a pencil, as shown, stretch the string, and, keeping the pencil in the angle thus formed, swing it round both above and below A B to form the curve required.

Perhaps the easiest way to set off an ellipse on a drawing is from two circles as shown in Fig. 129. Draw two centre lines

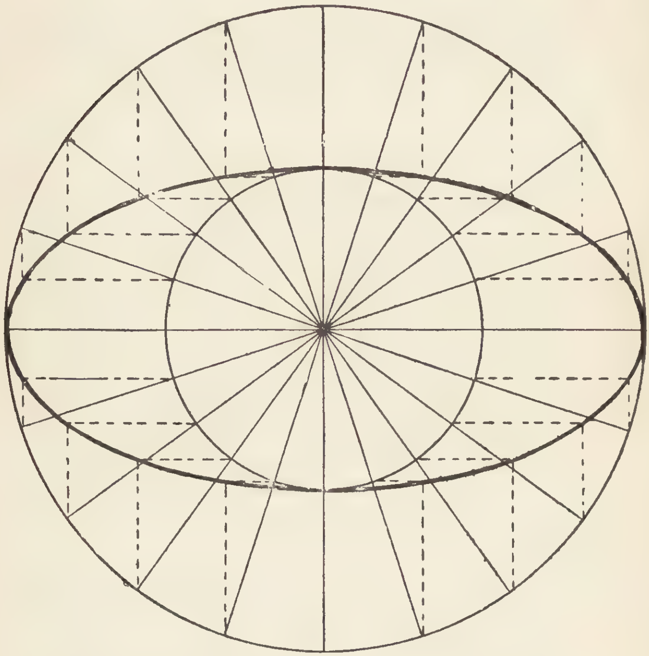


Fig. 129.—Ellipse Constructed from two Circles.

and describe circles equal to the major and minor axes of the required ellipse, say 7 in. and 3½ in.; then draw radii in any position, but preferably say every fifteen degrees (15°). If vertical and horizontal lines be now drawn from each radius where it is cut by the two circles, these lines will intersect at a point in the circumference of the ellipse, and the points may be joined by using a French curve as before described.

An approximate method of drawing an ellipse with compasses

to patch up the curve is shown at Fig. 130. Divide the major axis A B into three equal parts by the points C and D, and with each of these points as centres, radius equal to A C or D B, describe the small circles shown, cutting one another in the points E and F. Parts of these circles form parts of the ellipse, the remainders of the circles being shown dotted. To determine the extent of the full lines from each point of intersection, draw lines through the centres C and D to cut the circles. Then from centres F and E, with radius equal to F G or E H, draw tangent arcs to complete the ellipse, as shown.

The same method can be applied to draw an ellipse of different

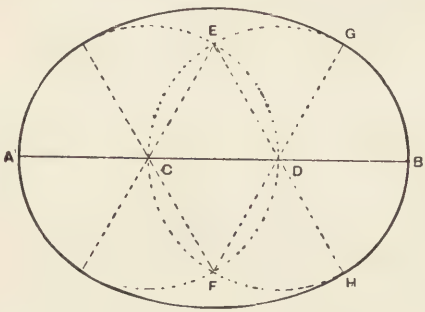


Fig. 130.—Approximate Method of Drawing an Ellipse.

shape as shown at Fig. 131. With A as centre, and C D as radius, mark the point E. Divide the distance E B into three equal parts. With O as centre and two of these parts as radius, cut line A B in M and N. With M and N as centres and with M N as radius, describe arcs intersecting in P and Q. With P and Q as centres and P D as radius, describe arcs T D V and R C S, and from M and N, with radius M A, describe arcs R A T and S B V to complete the ellipse. Lines drawn from P and Q through M and N show where the arcs join.

The method about to be described is not very scientific, but it is founded on accurate principles, and is both interesting and useful. Suppose we want an ellipse (Fig. 132), 9 in. long by 6 in. wide, which would be described by a mathematician as an ellipse whose transverse and conjugate diameters are respectively 9 in. and 6 in. First draw two centre lines at right angles to each other and rather longer than the above dimensions, then measure

off carefully from their intersection in each direction the required semi-diameter. Mark the horizontal line A, the vertical line B, the half minor axis $a\ b$, and the half major axis $b\ c$. Now

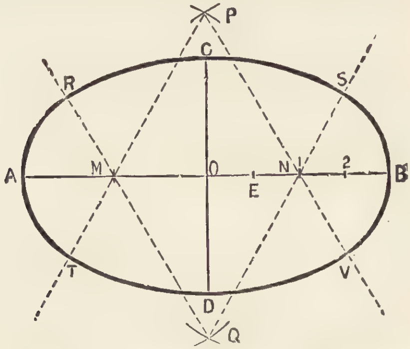


Fig. 131.—Another Approximate Method of Drawing an Ellipse.

prepare a slip of writing or drawing paper (Fig. 133) with one edge quite smooth and even; make a mark on this edge near one end, and sketch a hand pointing against the mark. Then

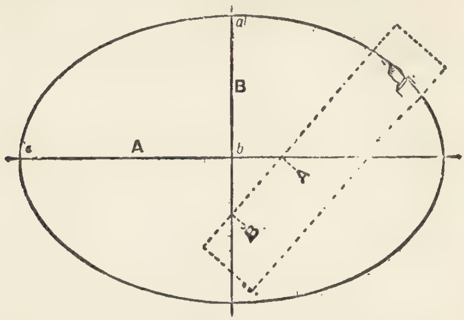


Fig. 132.—Drawing Ellipse with Paper Trammel.

measure off a distance equal to the semi-diameter $a\ b$ and make another mark, putting A against it; next measure off from the same point a distance equal to the semi-diameter $b\ c$, putting B against it. This paper trammel is now complete, and ready for service in constructing the ellipse; it is shown in course of use on the drawing (Fig. 132) by dotted lines.

If point A of the trammel be kept on the A line of the figure, and B on the B line, the hand will show where a pencil dot is to be made to give a point in the curve of the ellipse. Of course, it will be wise to go steadily round and put the dots about $\frac{1}{4}$ in. apart, seeing that they look even before joining them up. When

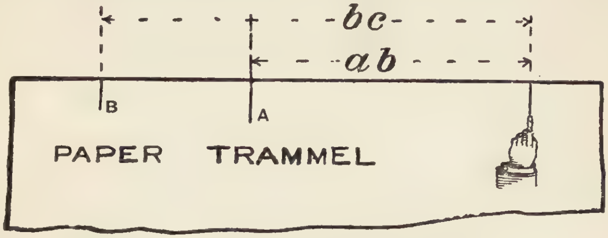


Fig. 133.—Paper Trammel for Drawing Ellipses.

this is done, a light thin line should be sketched continuously through all the dots, endeavouring at the same time to correct any irregularities. When the pencil curve looks all right, it may be inked in with the assistance of a French curve, such as is illustrated on p. 36. This thin slip of wood must be used with caution, finding a part that will fit the curve, say, from *d* to *e*

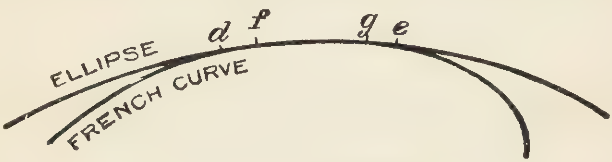


Fig. 134.—Use of French Curve.

(Fig. 134), and drawing only from *f* to *g*, so that there is always a piece at each end that appears to fit but is not used. By this method an ellipse will be obtained as regular in its outline as a circle drawn with compasses. It is worth taking some pains over it, because a good drawing of a machine may be spoilt by some little piece of curve, elliptical or otherwise, looking thick and ragged compared with others put in by compasses.

The method used by joiners and patternmakers to strike an ellipse is shown in Fig. 135. In place of the paper trammel used in Fig. 132 a piece of lath is taken, with a pencil inserted at ☞,

and French nails or stout pins at A and B. Then two straight-edges are placed against the major and minor axes so that the trammel may move along by the sliding of the pins over the lines, and each quarter of the ellipse can be struck in a continuous curve. The focus of an ellipse bears somewhat the same relationship to the curve as the centre of a circle does to the circle, but in the ellipse there are two of these centres or foci.

These are the points where the gardener puts pegs in the ground when he throws a loop of string over them to make a

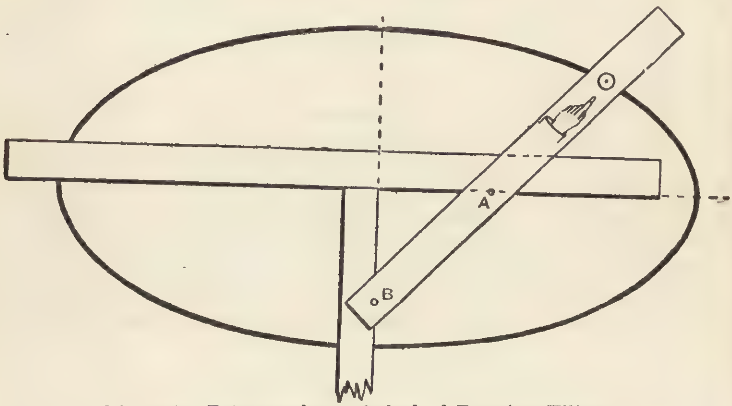


Fig. 135.—Patternmakers' Method of Drawing Ellipses.

so-called oval bed, although he will have to make several trials before he can hit upon a suitable proportion, through not knowing the proper method of setting about the work, which is done in the way shown by Fig. 136. First set out the two centre lines and decide what the two diameters shall be; then take the distance A B for radius, and with a string and couple of pegs for compasses, from the centres C and D strike arcs intersecting on the line A B in the points F_1 F_2; then F_1 and F_2 are the foci of the required ellipse. Drive pegs in at these points, and take a piece of string long enough to go right round F_1 C F_2, tie the ends to make it continuous, slip it over the pegs F_1 and F_2, and then with a stick P, starting at C, the whole ellipse can be struck in one continuous curve. There is no need to go into the garden in order to practise this method; two pins and a piece of cotton on a sheet of writing paper will demonstrate the problem equally well.

Brick arches are generally formed to the segment of a circle, and frequently occupy the exact half circle, when they are called

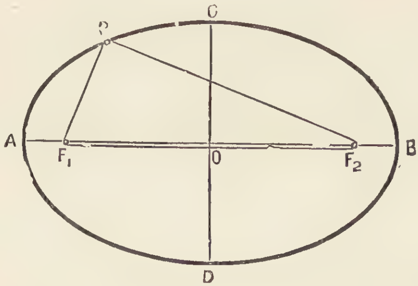


Fig. 136.—Gardener's Method of Constructing an Ellipse.

semicircular arches. In the ordinary way, an arch crosses at right angles to the opening it spans, but in the case of a railway

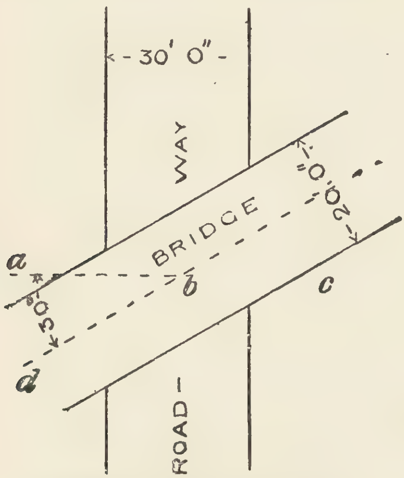


Fig. 137.—Plan of Skew Arch.

crossing a road diagonally, or a road crossing a canal similarly, a skew bridge is necessitated. In the accompanying plan (Fig. 137), a bridge is shown crossing a roadway with an angle of skew at

a b d of 30 degrees. The plan does not show whether it is a girder bridge or an arched bridge, but it would very likely be a

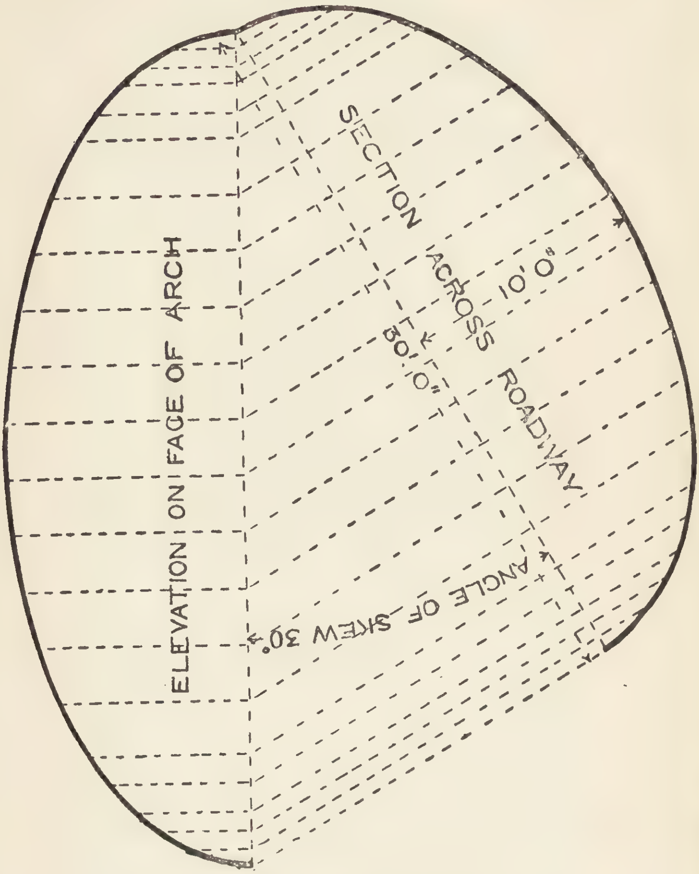


Fig. 138.—Elevation of Skew Arch.

brick arch having a semicircular soffit, that is, the section straight across the road in the direction *a b c* will show a semicircular outline on the underside.

In whatever way the arch may be built, whether with spiral

courses, as in a proper oblique arch, or in plain rings stopped off as they reach the face, as in some modern arches, the actual elevation on the face of the arch will be a semi-ellipse. We are, however, not tied to the semicircle for the normal section; we may have a segment of a circle, or a semi-ellipse, or any other outline which may be preferred, as the method of working given in the diagram answers equally for all shapes. As the reader has learnt to draw an ellipse, it will give the most practice to assume the normal section to be a semi-ellipse, and then the true elevation on face of arch will be another semi-ellipse with a longer major axis. To obtain this elevation (Fig. 138), draw a horizontal line, and at one end set off the angle of skew 30 degrees, and cut off the new line to a length of 30 ft., according to the scale it is intended to adopt, say $\frac{1}{4}$ in. to 1 ft. Then bisect that line, and set off at right angles to it from the centre a distance of 10 ft. to represent the rise of the arch, and by one of the preceding methods construct a semi-ellipse to show the section across roadway.

It often happens that very flat curves, or those with large radius, have to be drawn, and these the compasses will not reach. Some compasses, as described on p. 23, have a lengthening bar that will enable curves of 12 in. to 15 in. to be drawn, but this may not be sufficient. Then a trammel may be used, consisting of a lath with a sliding point and sliding pencil, enabling curves up to, say, 10 ft. radius to be drawn. There are, however, many cases where it is not convenient to use a trammel or any such instrument owing to the absence of a place to rest upon for the centre, and some more compact and ready means must be found.

In Fig. 139 let A B be the span and C D the rise of the required circular arc. With centre A and radius A B describe arc B E H, and from centre B with radius B A describe arc A F G. Through D draw A D E and B D F. Along the curves A G and B H at each side of E and F set off any convenient number of equal parts Join the points thus marked on the arcs with the centres from which the arcs were struck, then the intersections of the lines from E H with those from F A will give the required points for the curve from A to D, and the intersection of the lines from E B with those from F G will give the points for the part of the curve D B.

This results in a nearly true circular curve, but there are many cases where the curve need not be truly circular, and, as

a fact, when the rise is not more than one-sixth of the span it is almost impossible to distinguish between a circular arc and a parabola. This being so, we may adopt an easier method (Fig. 140), which gives clearer intersections. Let K L be the

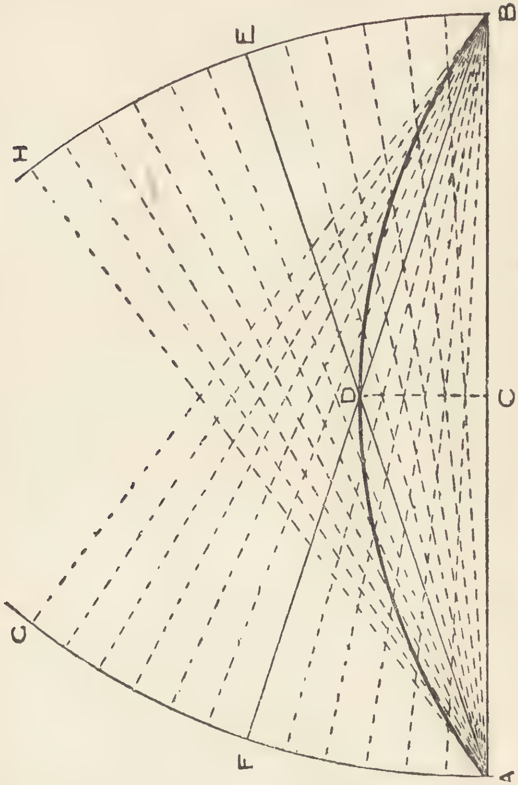


Fig. 139.—Circular Method of Setting Out a Flat, or Camber Arc.

span and M N the rise of the required curve; set K O perpendicular to K L and equal to twice M N, so that the point O lies in L N produced. Divide O K into any number of equal parts, and draw lines toward point L; divide K M into the same number, and draw vertical lines; the intersections will give points in the curve from K to N. For the curve from N to L repeat the operation

on that side—viz. by drawing the perpendicular at L, dividing it, and drawing lines towards K, then vertical lines on M L to give the intersections.

What is called a straight arch is very much used in brickwork over window openings. It is sometimes called a camber arch, because of the camber or slight curve given to the soffit. This camber is about $\frac{3}{4}$ in. to a span of 3 ft., or, say, $\frac{1}{4}$ in. per foot, and must be worked to by the bricklayer, but is not usually shown upon the drawings. Girders and girder bridges are made with a camber on the underside to improve the appearance; these also are not indicated on the drawing except by a written note, the

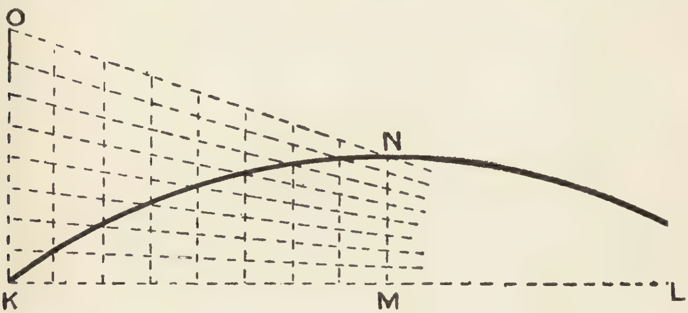


Fig. 140.—Parabolic Method of Setting Out a Flat Arc.

reason being that to draw them actually as constructed would involve considerable trouble with no corresponding advantage.

The parabola is such a very useful curve that no apology is needed in presenting some other methods of construction. It is the curve of equilibrium for an arch uniformly loaded across the span; it is also the curve of longitudinal stress in a girder loaded uniformly throughout its length. Besides these it enters in other ways into the shape of beams designed for uniform strength. The nature of the curve may be explained by supposing it to be the locus (that is, the successive positions or the route) of a travelling point, such that for any distances travelled in one direction it is displaced at right angles to that direction by an amount proportional to the square of the displacement first mentioned.

Useful methods of drawing a parabola are shown on the diagram (Figs. 141 or 142) for one half the curve, the other half being

similar. Draw horizontal and vertical lines representing the base and axis, mark off the semi-diameter and the height, and complete the rectangle. Divide the semi-diameter into twenty equal parts by vertical lines, and number them as shown. Now place a straight-edge or the side of a set-square in line with the lower left-hand corner of the figure and the point marked 10, and draw a line across the first division; from the termination of this line draw towards point 11 across *two* divisions, and from the new termination draw towards point 12 across *two more*

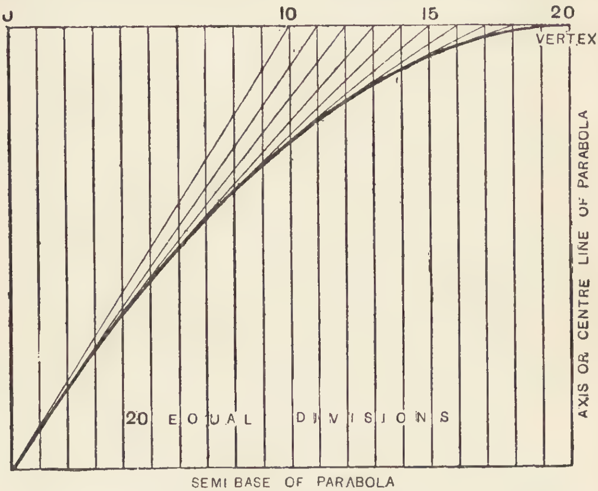


Fig. 141.—Parabola Constructed by Continuous Tangents.

divisions; and so on until point 19 is reached, when it will be found there is only one division to draw the last line across to point 20. By this means a parabola will have been formed approximately correct, but actually formed of short, straight lines. The tangent lines in the figure are shown drawn through to the top line, but in practice this is not necessary, and the verticals need not all be drawn through so long as they contain the curve and reach the top line between points 10 and 20.

The annexed diagram (Fig. 142) shows three methods of setting off a parabola, in one of which the law first stated is clearly shown; by the other methods it is not so evident. Draw

horizontal and vertical lines for the base and central height of the parabola and mark off a diameter of 12 in. and a height of 6 in. Complete the parallelogram, divide the base into sixteen equal parts, and draw vertical lines. Then for method 1 divide the vertical line at the extremity of the base into eight equal parts, the same number as in the semi-base, and from the vertex of the parabola draw lines radiating to these division points; the intersections with the vertical lines will give points in the curve which should then be sketched in neatly by hand and lined in with a French curve. If the lines are numbered as shown there will be no difficulty in marking the correct points for the curve.

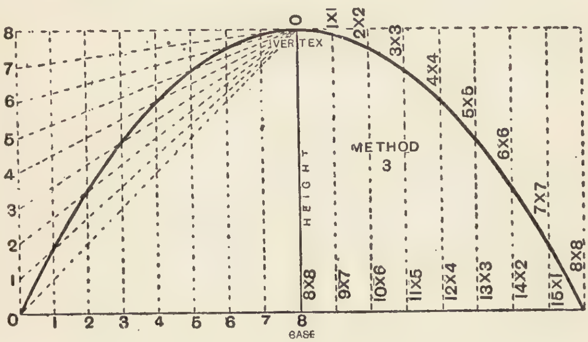


Fig. 142.—Three Methods of Constructing Parabola.

Method 2 is based upon the nature of the curve explained above, displacement at a distance of 1 being 1 squared $1^2 = 1 \times 1 = 1$; at a distance of $2 = 2^2 = 2 \times 2 = 4$; at a distance of $3 = 3^2 = 3 \times 3 = 9$, and so on, so that if we had a total height of sixty-four parts we should measure downwards from the top line, on each of the verticals, distances of 1 part, 4 parts, 9 parts, etc. As the total height is 6 in., we take $\frac{1}{64}$ of 6 in., $\frac{4}{64}$ of 6 in., $\frac{9}{64}$ of 6 in., and so on, *i.e.* $\frac{3}{32}$, $\frac{12}{32}$, $\frac{27}{32}$ of an inch, etc., and then draw the curve through. Method 3 is the complement of the last, and they are both very interesting because of the peculiar repetition of figures making it easy to remember the order. The total height is sixty-four parts, because we have eight divisions in the semi-parabola, and $8 \times 8 = 64$. If we had taken twelve divisions we should have had 144 parts in the height; the second

method would have commenced with 0, 1, 4, 9, etc., 144ths, and have continued beyond 8×8 up to 12×12 144ths. So in the third method with twelve divisions we should commence with 12×12 and have continued 13×11, 14×10, 15×9, etc., to 23×1, and 24×0.

Water spouting from an orifice, a shot fired from a gun, or a stone thrown from the hand, all describe parabolic curves in falling to the ground, and the line of flight is called the trajectory. In this connection it may be interesting to note that a ball fired from a level gun over a horizontal piece of ground would describe a parabola, and would reach the ground in the same time as a ball simply dropped from the mouth of a gun, the reason being that the fall of both is caused by the force of gravity acting equally on them.

The hyperbola is another of the conic curves. It is the curve formed on each of the faces in chamfering the bright hexagonal nuts used in machine construction. Sometimes a neat draughtsman will discover that the compass curve commonly used for showing the chamfering in the elevation of a nut cannot be made to fit the 45° line at the corner, but he may not know that this is because the curve is a hyperbola and that only an approximation can be drawn by the compasses. When steam expands in the cylinder of a steam engine the pressure is reduced, and if a horizontal line be drawn to represent the stroke of the piston, and the vertical heights representing the pressure as it changes be set off upon it, the points will approximate to a hyperbola, hence the expression "hyperbolic expansion curve."

On comparing this figure with the parabola it will be seen that the legs, as they may be called, of the hyperbola are straighter, and that the curved part of the former is narrower in proportion to the size.

There are several methods of setting off this curve, and the first (Fig. 143) illustrates one of its properties. Draw a horizontal line, called the asymptote, and set off any number of equal parts 1, 2, 3, etc., say $1\frac{1}{2}$ in. each; at 0 set up a perpendicular 8 in. long, or sixteen half-inches, giving point marked 16. This is to be the starting point of the curve. On point 1 set up half the height, or eight half-inches, on point 2 set up four half-inches, on point 3 set up two half-inches, and so on for as many divisions as have been made, each height being half the preceding. Now it

will be seen from this case that the hyperbola is a curve which continually approaches a straight line but never meets it, because, however many divisions may be taken, the distance from the asymptote is always half the last distance.

In the next figure (Fig. 144), two asymptotes are drawn at right angles, and $\frac{1}{2}$-in. squares marked off to facilitate the drawing of the curve. The axis of this hyperbola will be the diagonal of the figure, the curve being symmetrical on each side of it, so that this line passes through the vertex or highest part of the curve,

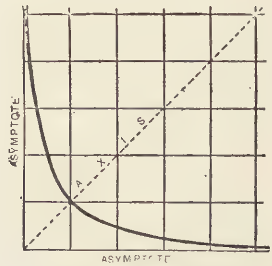


Fig. 144.—Hyperbola.

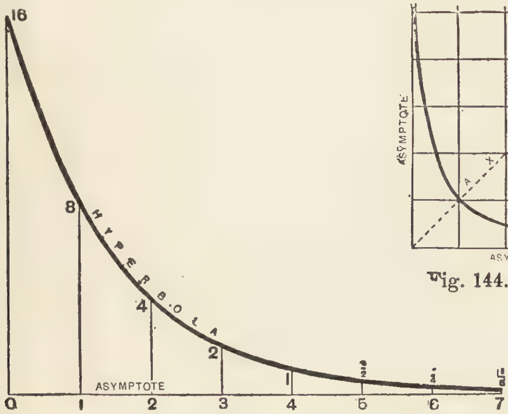


Fig. 143.—Hyperbola.

and the two sides or legs may be produced infinitely, but after about one more division each way the curve becomes practically a straight line.

To set out a hyperbola to fill a given rectangle (Fig. 145), draw a horizontal line A B, 6 in. long, representing the base of a hyperbola, and a vertical line C D bisecting it, 4 in. long, for the height to the vertex D. Produce C D, making D E equal to C D. Divide the base A B into any even number of equal parts, and the vertical lines above A and B each into half the number of parts; draw the converging lines as shown, and a curve drawn through the intersections thus formed will be a hyperbola.

The foundation for screw threads and for spiral staircases is

the helix. If a piece of paper be cut to the shape of a long right-angled triangle and rolled round a cylinder as in Fig. 146, the top edge of the paper will form the helix, and the pitch is the height reached in going once round. This helix is sometimes described as an inclined plane wrapped round a cylinder, which is practically what this experiment shows. Now, as in travelling up an inclined plane one continues rising at a regular rate, so on a spiral staircase every step is actually the same height and width; but in a picture of such a staircase the steps look narrower at the sides of the picture and wider in the middle, because the

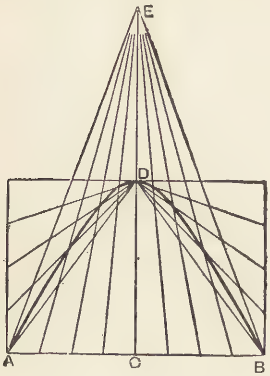


Fig. 145.—Hyperbola.

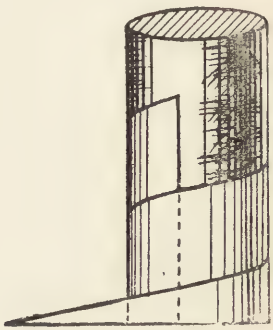


Fig. 146.—Helix.

outer edges are not in one plane; being bent round to a cylindrical form, the sides are foreshortened.

This will be better understood after the curve is drawn as shown by Fig. 147. Commence with the centre line A B. From point C in it describe a semicircle D A E of 3-in. radius, and through C draw the base line D C E, which should be horizontal. From D and E draw the vertical lines D F, E G, each 9 in. long, and then draw the upper horizontal line F B G. The rectangle D F G E represents the elevation of a cylinder. The semicircle D A E represents the plan of the front half of the cylinder, and upon it are set out the successive steps. With radius C D, mark off D L, A M, A N, and E O, then bisect D M, M L, L A, A O, O N, and N E; this will have given twelve equal divisions upon the semicircle from which vertical lines must be drawn as shown. If the curve is to rise

from point D with a pitch of 4 in., it will rise half that, or 2 in. in the front or visible half and 2 in. in the back or hidden half, and so on for any number of turns of the spiral; therefore draw horizontal lines, half pitch apart, through H, I, J, and K, as the same curve will be found to repeat itself in each of these divisions.

As twelve divisions have been made on the semicircle, so twelve divisions must be made between D and H, and horizontal lines drawn through as shown. This will give a series of intersections through which the curve must be drawn; one along and one up, two along and two up, and so on for the right points. When this much of the curve has been put in, the remainder

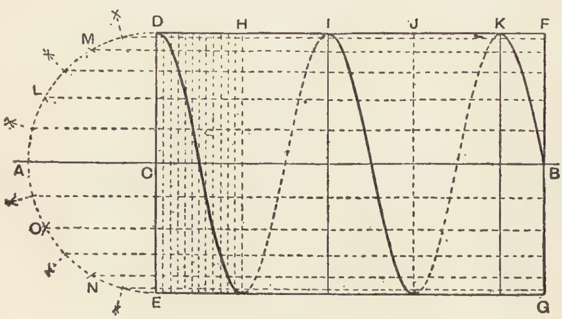


Fig. 147.—Projection of a Helix.

can be most readily drawn by using the half pitch lines I, J, and K, and with the compasses or bow pencil marking off upon the verticals all the places where the curve is one division up or down, then two divisions, and so on. Dot the curve on the back of the cylinder, and observe that, if correctly drawn, the helix will not form a point at I or K, or similar parts, but will really be vertical for a very small distance, giving the effect of a rounded turn.

The curve, with which this chapter will close, is called an "entasis," and was designed to meet the æsthetic taste of the ancient architects. They knew that a long column was scientifically inaccurate if made parallel, owing to the greater weight carried by the lower part, and they thought the straight taper looked ugly, so they made their columns with a slight

swell in the diameter between the two ends. The optical effect of the entasis is to increase somewhat the height. Metal under compression bulges before it gives way, and hence the bulging here gives the feeling of supporting a load and not of being

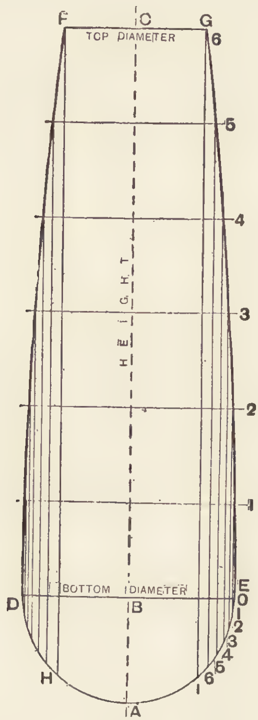


Fig. 148.—Entasis of Column.

merely ornamental; besides that, a column with a straight taper appears to be slightly hollow at the sides.

In the illustration (Fig. 148), the diameters are taken very large in proportion to the length, in order to show the method and result more clearly. There are various ways of setting off this curve; the one shown is known as Tredgold's. Suppose the length between the mouldings of the cap and base to be

12 in., the top diameter 3 in., and the bottom diameter $4\frac{1}{2}$ in.; these dimensions might represent a heavy cast-iron hollow column to a scale of 1 in. to 1 ft., but the result is altogether too stumpy for a stone column; nevertheless, the same principles apply whatever the length may be. Draw the centre line A B C, making B C equal to the length; then draw the two diameters D E and F G. Upon D E construct a semicircle D A E, and from F and G, drop perpendiculars to meet the semicircle in points H I; then divide the arcs D H and I E into any convenient number of equal parts, and the height B C into the same number of parts. Draw horizontal lines through the divisions on the centre line, and vertical lines to meet them from the divisions on the semicircle; the intersections will give points in the entasis, and a French curve may be used to obtain a properly flowing curve through the points.

The curves described in this chapter have been specially adapted for working on sheets of drawing paper, and when completed the set of twelve sheets will certainly be interesting, and, it is hoped, will also be useful to the draughtsman.

CHAPTER VI.

PROJECTION.

It will be advisable to give some attention to projection before going on to shading and shadows. The method of putting a plan below an elevation, and a section at the side of it as usually practised by draughtsmen, is known technically as orthographic projection on vertical, horizontal, and profile planes. The general idea of merely drawing the various parts exactly in the same line in the different views, or opposite each other, is very simple, but

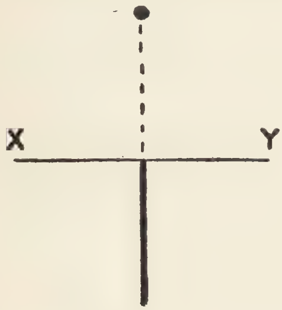


Fig. 149.

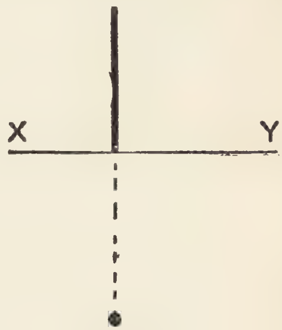


Fig. 150.

Projections of Lines.

cases arise where a draughtsman who has not studied descriptive geometry finds himself unable to proceed, as, for instance, when parts are not at right angles to one or other of the planes. The ease of executing ordinary cases of projection, and the difficulty of overcoming the unusual cases, are well illustrated in the accompanying diagrams (Figs. 149 to 155), in which the following seven problems are worked out, but only the last two will require a detailed explanation. X Y is the line of intersection between the vertical and horizontal planes, which are here supposed to be laid flat on the paper, one above and one below the line.

Fig. 149. A line $1\frac{1}{2}$ in. long, touching the vertical plane, and at right angles to it, parallel with the horizontal plane and $1\frac{1}{2}$ in. above it.

Fig. 150. A line $1\frac{1}{2}$ in. long, touching the horizontal plane and at right angles to it, parallel with the vertical plane, and $1\frac{3}{4}$ in. rom it.

Fig. 151. A line $1\frac{1}{2}$ in. long, parallel with both planes, and 1 in. from them.

Fig. 152. A line $1\frac{1}{2}$ in. long, parallel with the vertical plane and 1 in. from it, $\frac{1}{2}$ in. above the horizontal plane, and making an angle of 45° with it.

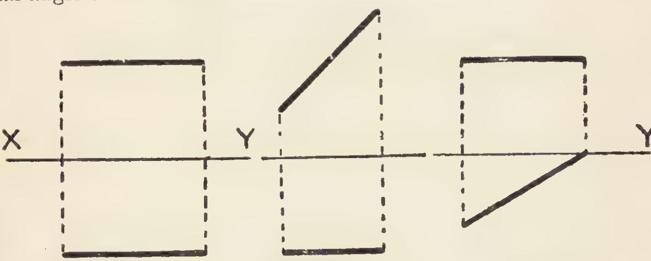


Fig. 151. Fig. 152. Fig. 153.

Projections of Lines.

Fig. 153. A line $1\frac{1}{2}$ in. long, parallel with the horizontal plane and 1 in. above it, touching the vertical plane, and making an angle of 30° with it.

Fig. 154. A line 6 in. long, touching the intersection of both planes, making an angle of 30° with the horizontal plane and 25° with the vertical plane.

Fig. 155. An oblique plane cuts the horizontal and vertical planes, making an angle of 60° with the former and 45° with the latter ; show the traces of its intersection.

In Fig. 149 the length of line is measured from X Y in the plan, and the height from X Y in the elevation. In Fig. 150 the reverse. In Fig. 151 the length is measured in either plane, and the distance in both. In Fig. 152 the length of line is measured in the vertical plane, where its full length can alone be seen. In Fig. 153 the length is measured in the horizontal plane for the same reason. In Fig. 154 the line is inclined to both planes, and annot be measured off directly, as in the previous cases. First measure the required length of line *a b* on X Y, then from point *a*,

with radius $a\,b$, describe the arc $c\,b\,d$, making $c\,a\,b$ 30°, and $b\,a\,d$ 25°. Then $a\,c$ represents the line at an angle of 0 degrees from the vertical plane, and $a\,d$ the line at 0 degrees from the horizontal plane. In each case the line has to swing round on a vertical axis through a to reach its required position; all we know at present is that one end of the line will be at a and the other somewhere in the lines $c\,e$ and $d\,f$, parallel with X Y. Drop

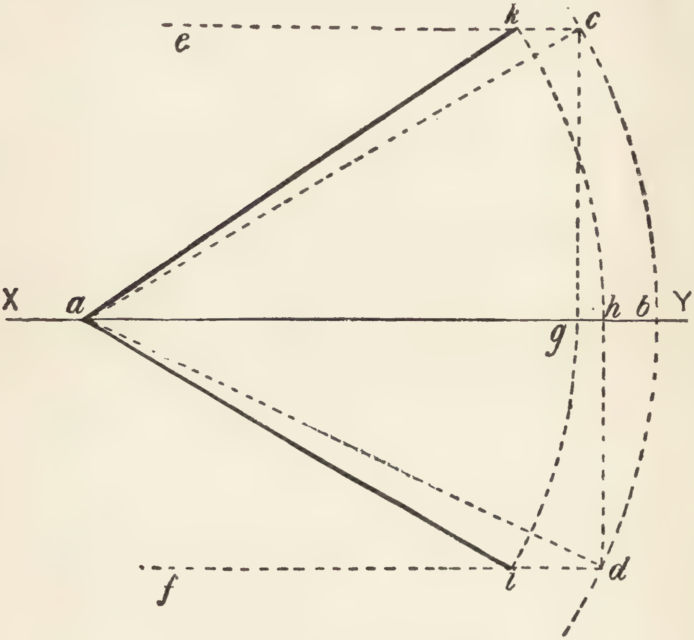


Fig. 154.—Projection of Line.

perpendiculars from c and d, cutting X Y in g and h, then $a\,g$ will represent the line in plan when raised up to the required angle from the horizontal plane, but coinciding with the vertical plane. Now by radius $a\,g$ swing it round to cut $f\,d$ in point i, then $a\,i$ will be the true plan of the line. In the same way $a\,h$ represents the elevation of the line when lying on the horizontal plane, but making the required angle with the vertical. Now from the centre a with a radius $a\,h$ describe the arc $h\,k$, cutting

c e in point *k*, then *a k* will represent the true elevation of the line under the required conditions. If correctly drawn, point *k* ought to be vertically over point *i*.

Fig. 155 presents a rather more difficult case. The principle

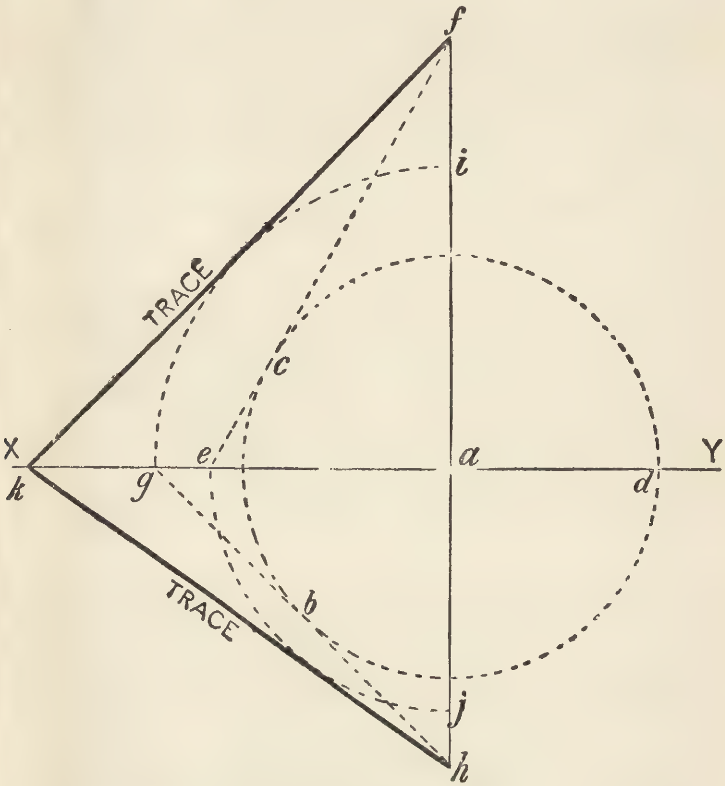


Fig. 155.—Projection of Line.

upon which it is to be constructed is to assume a sphere whose axis is X Y, to the surface of which the required plane shall be tangent. Draw a line at right angles to X Y, cutting it in any point *a*. From point *a* as a centre with any radius describe the circle *b c d* to represent the sphere just mentioned. Draw lines *e f*

and gh tangent to the circle at c and b, and making the required angles fea 60° and agh 45°. From a, with radius ag, describe the arc gi, and from a, with radius ae, describe the arc ej, then from points f and h, tangent to these last two curves, draw the required traces fk, hk, meeting accurately in point k when properly drawn. The rationale of the process is that gic and ejb are parts of a conical surface to which the plane is tangent. It must be noted that the sum of the two given angles must always be between 90° and 180°; at these extremities the traces of the plane will be parallel with X Y when the combined angle is 90°, and perpendicular to it when the combined angle is 180°.

For working drawings of buildings or machines the ordinary

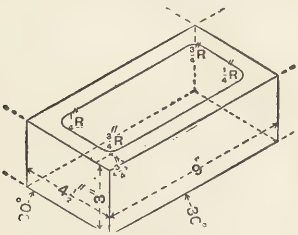


Fig. 156.—Brick in Angular Projection.

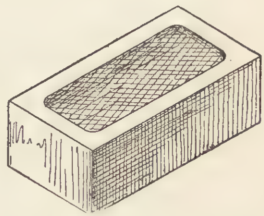


Fig. 157.—Shaded Sketch of a Brick in Angular Projection.

plan, elevation, and section are best suited, and are clearly understood by most, if not all, persons requiring to use them. To persons unacquainted with draughtsmen's work they convey only a vague idea of what they are intended to represent, and this is why perspective drawings are so much in vogue for representing the complete view. Perspectives are simply representations of objects as they would appear in a good photograph. Formerly any printed illustration had first to be drawn out by hand, so that its accuracy was largely dependent on the skill of the draughtsman; the difficulty was most pronounced in the case of machines, as any old journal or catalogue will testify. Now photographs can be adapted for reproduction, and illustrations of machines are produced with exactness and at very small cost.

A still simpler method of projection may be applied to small details, which is often incorrectly called isometrical projection;

strictly, it is pseudo-isometrical (that is, false isometrical), but is conveniently known as "angular projection." It is based on exceedingly simple rules, which may be summarised as follows: Horizontal measurements are taken along lines inclined at 30° to the base line, and vertical measurements on vertical lines. This will be made clear by taking the drawing of a brick (Fig. 156) say, 9 in. by $4\frac{1}{2}$ in. by 3 in. (that is, large enough to include thickness of joints) to a scale of half full size.

Let one corner of the brick (Fig. 156, p. 96) touch the base line, then draw a vertical line cut off 3 in. long, and lines inclined to the base 30° each way cut off $4\frac{1}{2}$ in. and 9 in. long. Draw vertical lines from the ends of the inclined ones, and inclined lines from

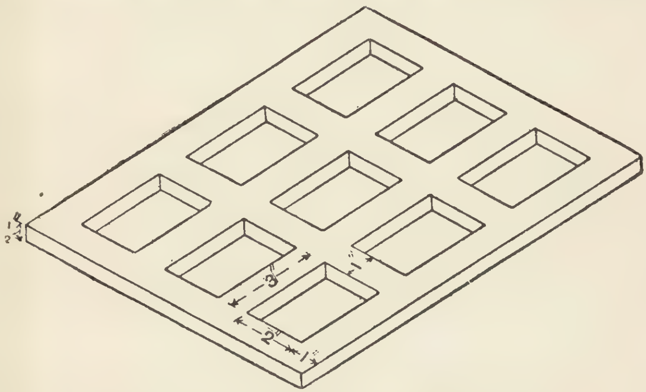


Fig. 158.—Iron Grating in Angular Projection.

the end of the vertical; then two sides of the brick will be completed. Next, draw inclined lines from the farther corners of the two sides to meet above and the brick will be completed in outline. To obtain the frog or key on top of the brick, supposing the flat margin to be $\frac{3}{4}$ in., measure $\frac{3}{4}$ in. from each angle and draw intersecting lines. To obtain the curves at the angles of the frog in hand-made bricks, suppose them to be in reality $\frac{1}{2}$-in. radius, the compasses may be used at radii of $\frac{1}{4}$ in. and $\frac{3}{4}$ in., as shown; this is necessary to give the effect produced by viewing the curves on an inclined surface.

An angular projection has the advantage of appealing more directly to the uneducated eye than the ordinary plan and eleva-

tion do. It should never be back-lined as ordinary plans are, for the reason that relief is already effected, and back lines would only reduce the effect. Angular projections may, however, be coloured, and shaded if desired, as in Fig. 157. In further illustration of the subject, a small cast-iron grating is shown (Fig. 158), ½ in. thick, bars and margin 1 in. wide, openings 3 in. by 2 in.

The angular projection, shown above, has the advantage over either perspective or true isometrical projection, that an ordinary 2-ft. rule may be used upon the drawing to ascertain any of the dimensions. For showing the details of joints in carpentry and joinery, angular projection is especially appropriate, and it will soon be found by the draughtsman that the angular directions of 30 degrees each way for the horizontal lines need not be adhered to when some other angle will be more convenient. Convenient and simple as this is for details, it would not be suitable to take the place of perspective for complete views of houses, as the eye would then revolt from what would appear to be distortion. The eye is so accustomed to true perspective in nature and the fairly accurate representations of photographs and artistic sketches, that a house in angular projection would appear to be swelled out behind, because where one expects to find the taper, no taper would be given. If the simplest possible outline of a house be drawn in angular projection, it will serve to show the method by which any required points are found, so that any other case that may arise may be worked out on the same principles.

Draw first a plain front and side elevation (Figs. 159 and 160), so as to get the various parts in their right proportions, then, remembering that vertical lines remain vertical, while horizontal lines are drawn at 30° from the horizontal in either direction, no difficulty will be found in completing the lower portion of the house, the measurements being taken in the same direction as the various lines are drawn. For the roof it will be seen that if the position of the ridge can be found, the hips will simply be drawn up from the angles to meet it. Bisect the eaves line on the visible end of the house and draw a line through at 30° from the horizontal to meet the other side ; bisect this line and set off half the length of ridge on each side of the bi-section, and from the extremities of the ridge length draw vertical lines, cutting them off at a height equal to the height of ridge above eaves, as seen in elevation, and join the ends. This will give the ridge itself, and, the ends being joined to the four corners, the hips are produced.

To put on the chimney stack, observe first that the penetration of the roof in the front elevation is obtained by noting the distance vertically down from the ridge to where the sides cut the roof planes in the end elevation. Then draw a vertical line from

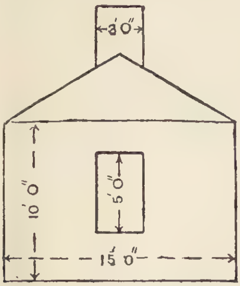


Fig. 159.—Side Elevation.

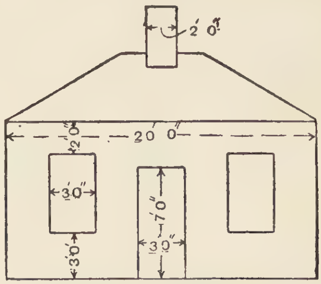


Fig 160.—Front Elevation.

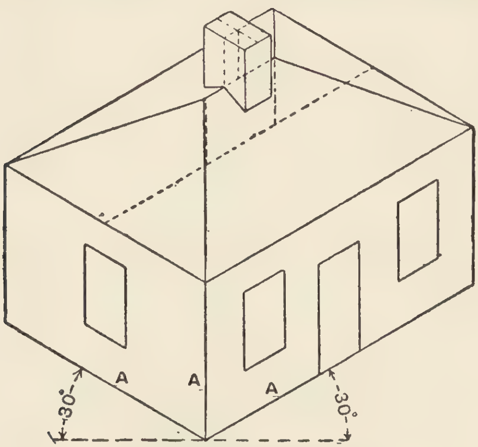


Fig. 161.—Angular Projection.

the centre of the ridge in the angular projection, cut it off to the height of the chimney stack, and the top point will be the centre of upper end of stack. Through this point draw centre lines at 30° each way and mark off the width and breadth of the stack, and through the four points thus found draw four lines parallel

with the two centre lines. Now draw vertical lines downward from the three near corners and cut them off equal in length to the height of the stack on the end elevation. Drop a vertical

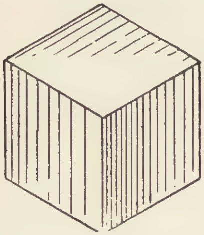


Fig. 162.—Sketch of Cube.

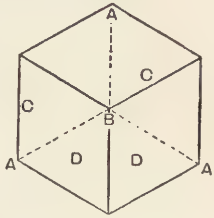


Fig. 163.—Geometrical Construction of a Cube.

line from the centre line at top of stack down the wide face to meet the ridge, and join up the intersection lines as shown in Fig. 161.

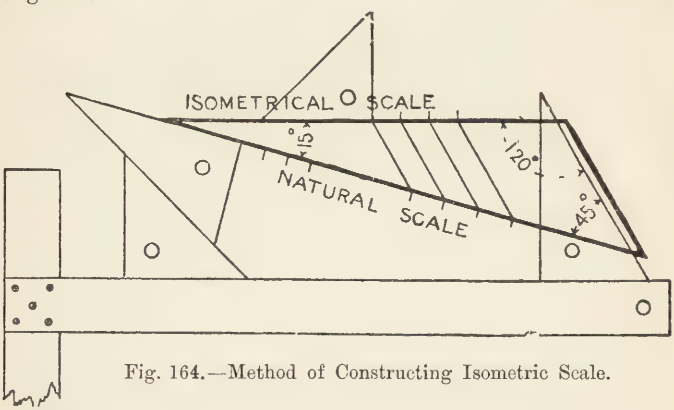


Fig. 164.—Method of Constructing Isometric Scale.

Before concluding this chapter on angular projection, it will be interesting to see the principles and application of true isometrical projection. It is based upon orthographic projection—that is, the rays of light proceeding from the outlines of the object travel in parallel lines, and not in converging lines as in perspective. In this it very much resembles the angular projection just illustrated, but it differs from that in having the

inclined lines all foreshortened to make a true projection. For instance, if a cube of 3-in. side be drawn in isometrical projection, the edges will be foreshortened to about $2\frac{3}{8}$ in. to make a

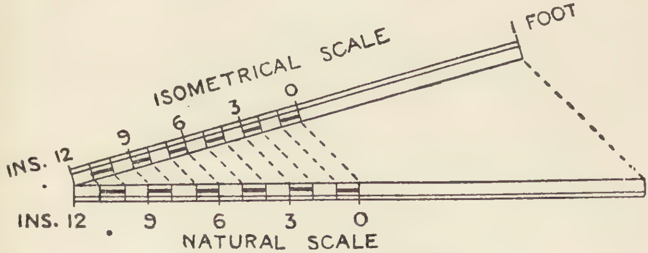


Fig. 165.—Isometric Scale.

true representation ; or, more accurately, the natural scale is to the isometrical as 1 to $\sqrt{\frac{2}{6}}$ or, roughly, as 11 to 9. In this method the object is supposed to be tilted up to show three faces; or, taking a cube as best illustrating the principles, it is

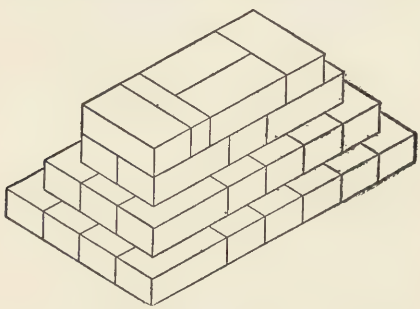


Fig. 166.—Example of Isometric Projection.

placed so that a direct line from the eye passes diagonally through the cube as shown in shaded sketch (Fig. 162), or geometrically by the outline (Fig. 163). Certain terms are used in describing the different parts of the figure ; they are —A A, isometric axes ; B, the regulating point ; C C C, isometric lines ; D D, isometric planes. The scale may be constructed readily by the use of T and set squares as shown, the sketch

(Fig. 164) giving the method, and Fig. 165 the result. As an example of the application, the end of a one-brick wall is shown (Fig. 166), from which it will be seen that there is no advantage over common angular projection, for which an ordinary scale can be used.

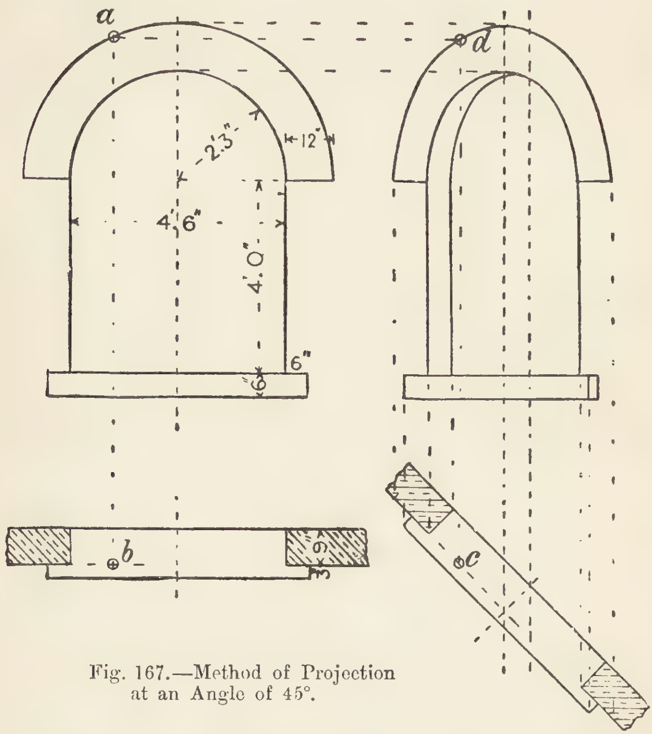


Fig. 167.—Method of Projection at an Angle of 45°.

In drawing an elevation, difficulty sometimes is experienced when one face of the work, or one side of the building, is not square to the front or parallel with it. Common instances are shown on the accompanying diagram (Fig. 167), and the method of projection scarcely requires any explanation. Draw first the natural elevation and plan of the window opening to the required scale (Fig. 167). Then assuming that the wall makes an angle of

45 degrees with the spectator, draw the plan of it, marking the centre line, and also a cross centre line for face of arch. Project lines upward from each angle, and also from the centre line at face of and back of arch. Then from the elevation project lines from each point to intersect those drawn from the angled plan, and draw in the straight outlines.

The circular curves in the elevation will become elliptical in

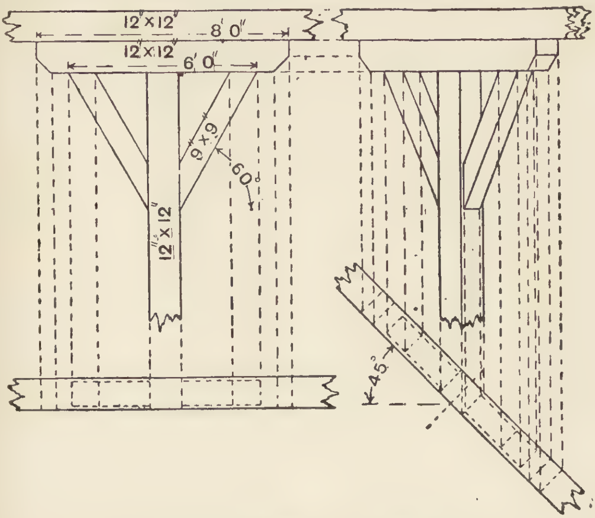


Fig. 168.—Projection at an Angle of 45°.

the angled elevation, but they can be obtained by intersections, the same as any other parts of the outline. A point on any part of any curve in the elevation as *a*, being projected down to the plan as *b*, transferred to the angled plan as *c*, and projected upwards to intersect at *d*, with the horizontal projection from the same point, shows the method by which the whole outline may be obtained; a sufficient number of points being found, the curve is sketched through by hand and afterwards inked in with the aid of a French curve, such as is described on p. 36.

The illustration (Fig. 168), showing part of a gantry, is upon the same principles, and there can hardly be found any difficulty in working it out according to the copy.

CHAPTER VII.

BACK-LINING DRAWINGS.

THE following seven figures deal with the back-lining of drawings. The ordinary plan or elevation of an object often seems to the novice nothing more than a mass of lines, while, even to one experienced in reading drawings, some little study is necessary when dealing with the representation of a new object. A mechanical drawing, if left in outline and uncoloured, requires an expert to understand it, unless it is some very simple subject. There is nothing to indicate which parts are round and which are flat, which stand out and which recede, so that some acquaintance with the object represented is necessary to be able to "read" the drawing. A simple method of removing this difficulty is to "back-line" the drawing—that is, to thicken the outline on the shady side of all projections. This, however, has to be done by rule in order to obtain the greatest advantage from its use.

For uniformity, the direction of the light is always supposed to come from the top left-hand corner, and to strike the paper at an angle of 45°. The arrow on p. 105 may be supposed to be a plan of a ray of light, and if one of the short sides of a 45° set-square be placed on this line perpendicular to the surface of the paper with the point towards the arrow-head, the long side of the set-square will represent the ray.

If a solid, such as a cube, be supposed to stand on the paper in these rays of light, the sides nearest the top left-hand corner will be bright, and the opposite sides dark and casting shadows. Wherever there is an edge casting a shadow, the line representing that edge is thickened.

The examples shown in Figs. 169 to 172 introduce the projection of plans and elevations from each other. If a simple body like a cube of 2-in. side, is placed in front of the eye, with one side "full-face," then the elevation is seen; to look down on top of it will show the plan, but there will be no difference in the two views except a difference of position. Upon the drawing paper

the upper part is used for elevations and the lower part for plans, the corresponding views being placed exactly one under the other, the corresponding points being "projected," or drawn with the pencil and square.

Suppose the 2 in. cube to be cut into halves horizontally, and the upper half of the cube to be removed, and the lower half to be turned round so that a corner will be nearest the eye, and that a smaller cube—say $\frac{1}{2}$ in.—be placed on the top of it in a similar position to that occupied by the cube in Fig. 169, then the elevation and plan will give the two views shown in Fig. 170. These should be carefully studied, and the meaning of projection

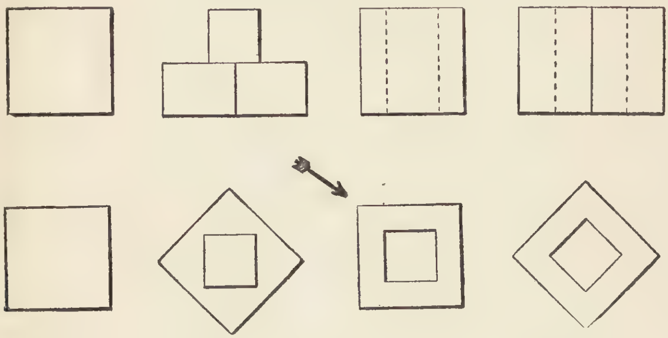


Fig. 169. Fig. 170. Fig. 171. Fig. 172.

Projections of Plans and Elevations of Rectangular Objects.

tested by trying various points, and having recourse to other objects, if necessary, to illustrate the different appearances of plan and elevation.

The next pair (Fig. 171) shows a cube in the same position as that in Fig. 169, but having the interior cut out by a hole $\frac{1}{2}$ in. square made through it, as shown in the plan. In the elevation the hole cannot be seen, but its position can be indicated by dotted lines; and this shows one advantage a drawing has over a picture: the inside of an object can be shown as well as the outside.

In Fig. 172 the hollow cube is turned diagonally, so that an edge is presented in the elevation. By this time the construction of the various figures will be pretty well understood, and they may now be drawn in pencil, all lines being thin. The

elevations of the diagonally placed figures must be projected from the plans to get the right width, and it is well to test the plans themselves to see that they are correct before drawing the elevations. The principle of the test is that in any rectangular figure the two diagonals are equal. In inking-in, the outlines may be made thin first, and then the additional thickness added on to the outside (that is, the side the shadow is), or the thick lines may be put in direct. The following rules may be given :—Lines representing surfaces casting a shadow should be thick; lines representing edges only casting a shadow should be medium, and all other lines thin.

Referring to Fig. 170 in the elevations, the right-hand line of the small cube represents a surface as well as an edge ; it is a surface edgeways and casts a shadow : therefore it is made thick. The under side of the large half-cube represents two edges and one surface, and casts a shadow ; therefore it is thick. The middle line and the right-hand line of this half-cube represent edges only, as the surfaces themselves are visible, and the lines are made a medium thickness between that of the thin and the thick lines. All the other lines of this figure are usually made thin. When any doubt exists, imagine the drawings to be solid objects and move the set-square over them.

After the previous illustrations the following three figures will be comparatively easy, as they illustrate only an extension of the same principles. They show the application of back-lining to curved surfaces, Fig. 173 being a cylinder, Fig. 174 a small cylinder on top of a larger, and Fig. 175 a cylinder with a hole through it.

In Figs. 170 to 172 has been shown how relief is given to flat surfaces representing rectangular objects, but there are two lines about which some doubt may have been felt—the right-hand top edge of the lower part of the elevation (Fig. 170) and the same part of the elevation in Fig. 172. Although these lines are part of the boundary of surfaces in the shade, they do not strictly come under the definition of edges casting shadows, and are left thin. It will be observed that the back lines—or shadow lines, as they are sometimes called—are applied as if the object itself were moved on the paper in plan and elevation, whereas, in practical geometry, the rule is to consider the object immovable and the paper bent at right angles, between the plan and elevation, to receive the projections of the various points on the

outline. The latter method must be followed when a systematic study of shadows is made, and then the shadows in plan are projected diagonally upward from the bottom left-hand corner. The method shown in the series of illustrations (Figs. 173 to 175) is much simpler and more convenient.

In Fig. 173 is shown a cylinder 3 in. long and 3 in. diameter; in Fig. 174 a cylinder 3 in. diameter and $1\frac{1}{2}$ in. long, with another $1\frac{1}{2}$ in. diameter and $1\frac{1}{2}$ in. long standing upon it; and in Fig. 175 a cylinder similar to that in Fig. 173, with a $1\frac{1}{2}$ in. hole through it. The plans must be drawn first, each circle being struck from

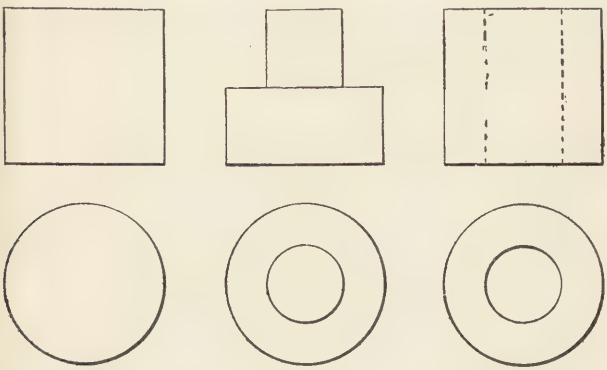


Fig. 173. Fig. 174. Fig. 175.

Projections of Plans and Elevations of Curved Objects.

the intersection of two centre lines, and then the elevations projected from them. It is better to ink-in with all thin lines and to add the back lines afterwards; they are then more likely to be correctly placed outside the outline. In the elevations the bottom lines represent surfaces, and cast shadows, so that they will be made thick. The right-hand lines represent edges only—that is, the extreme projecting parts of the curves—and cast shadows; therefore they will be made of medium thickness and the remaining lines thin. In the plans the lines all represent surfaces, but only parts of the lines cast shadows. The thick lines require to be eased off into thin ones without showing any abruptness, an operation which requires some little skill.

Instead of opening the nib of the compasses to make a thicker

curve, they should remain as for a thin line, and the centre should be shifted from the intersecting point of the two centre lines downwards to the right at an angle of 45°, about the hundredth of an inch, so that the drawing of a second half circle will give a thickening that dies off gradually at the opposite 45°. Repeating this about three times will give a line of the required thickness and properly eased off at the ends. The thicker line becomes tapering because the radius is virtually increased in the one direction only, remaining practically unaltered in a direction at right angles to the shifting centre.

The difference between a projection and a recess are clearly shown in the difference between the inner circles of Fig. 174 and

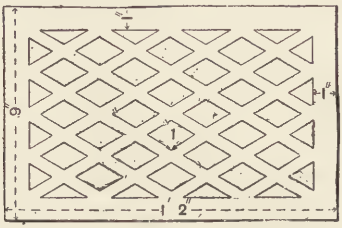


Fig. 176.—Cast Iron Grating.

Fig. 175, the edge casting the shadow being thickened in each case. If much difficulty is experienced in producing neatly the curves with one side thickened, it will be found very good practice to draw, say, a dozen concentric circles, with $\frac{1}{4}$ in. differences between the radii, and back-line them all.

Geometrical solids, such as those shown in the last seven figures, are better adapted for illustrating principles than ordinary objects are, but they are not so interesting. But having learnt the method of back-lining, the knowledge can be applied to such drawings as it may be desirable to improve, without the labour of shading and colouring. Fig. 176 shows a small perforated grating of cast iron arranged in diagonal bars with lozenge-shaped spaces. The rim or frame of the grating is 1 in. wide, the bars $\frac{1}{2}$ in. wide and 1 in. apart; the thickness, not shown, is $\frac{1}{2}$ in., and the over-all dimensions are 14 in. by 9 in. The illustration is to be re-drawn full size.

Commence as usual with the border line, then take 9 inches

in the scale or dividers, and mark where to put the bottom line of the grating on the paper, allowing room for the heading and statement of scale. Rule in this line with the T-square, measure the length so as to leave it central on the paper, and then put in the double lines for the 1 in. width of rim. Now draw diagonals across the grating from the inside corners; and on looking at the illustration it will be seen that these diagonals pass along the centre of two of the bars, and give the direction of all the others. It is very easy to go wrong, but if correctly set off, there will be exactly half-lozenges all round the outside, and the distance between the points will be exactly equal to the distance between the points of the whole lozenges in the interior.

If there were bars in one direction only, very few would make any mistake in the measurements, but the bars crossing each other cause many to measure the 1 in. distance apart along one of the lines of the other set of bars, instead of at right angles to the bars which are being set out. At first sight it may appear that the dimension 1 in. between the bars near the centre of the illustration is twisted out of place; it is, however, correctly placed, and shows the direction in which the measurement must be taken. Being full-size, the drawing does not require a scale at the bottom, but the dimensions should be figured in, as they establish the precise size required, and to some extent render the work independent of the accuracy of the drawing.

In most specifications of work to be done, a clause is inserted stating that—"Where any discrepancy exists between the scale of a drawing and the figured dimensions, the latter are to be worked to, unless obviously incorrect." When the back-lines are put outside the solid parts, accurate measurements can be taken from the drawing with as much facility as if all the lines were thin; but to be useful, this rule must have no exception. If the bars in the illustration had been at an angle of 45°, instead of about 30°, as at present, only those going upwards from left to right would be entitled to back-lines, although generally the others would have them also for the sake of effect; in that case the lower sides of the other bars would receive the back-lines, although having no more right to them than the upper sides.

Owing to the thickening up of the thin lines unavoidable in printing, there may be some doubt, in looking at the illustration, as to which lines are there intended to be back-lined; but if the grating be looked upon as an actual object resting on the paper

with the light shining down diagonally from above the top left-hand corner, it will be evident which lines would cast shadows.

Reversing the type of illustration given in Fig. 176, a cover-plate of the style known as "chequered," for placing over an opening such as a valve-pit, manhole, etc., may be drawn. The chequers, or raised pieces, are to prevent slipping, and give a firm foothold when passing over it. In this case only one corner of the plate is shown on the drawing; the remainder being apparently broken away. This is a method frequently adopted in drawings when there is much repetition work about the object, and the drawing is desired upon a large scale. The outside

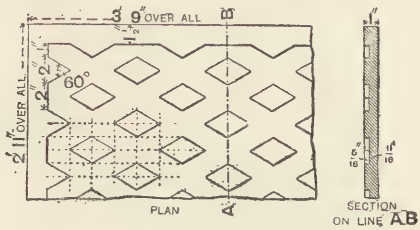


Fig. 177.—Chequered Plate.

dimensions show that the whole plate is 3 ft. 9 in. by 2 ft. 11 in., and calculation will show that this will allow for six chequers in length and eight in width. Another method sometimes adopted is to show the outline of the whole plate to a small scale, with a few of the chequers in one corner, and perhaps a single chequer full-size with the dimensions to it.

A section is the surface exposed by an imaginary cut, and the "section on line A B" shows the surface that would be exposed at that particular part. The hatching or diagonal lines show the cut surface, the projecting parts on the left being the chequers that are cut through, and the light parts between them, the ends of the other chequers seen in the distance. The chequers stand out $\frac{5}{16}$ in., the total thickness being 1 in.

In making this drawing (Fig. 177) commence with the top line, and follow with the left side; set off the width of rim or plain edge, then divide the inner edge of left-hand side all the way down according to the dimensions given, bearing in mind the

required scale. Then with the 60° and 30° set-square, set off the projecting points or half-chequers, and see by the T-square that they all come in line.

From this stage onwards there are various methods of working; perhaps, on the whole, the following will be the best:—From the inside of the rim draw horizontal lines 1 in. apart (to the scale required), and vertical lines $1\frac{3}{4}$ in. apart, similar to the few that are shown by dotted lines on the illustration. Then by joining the proper intersecting points as many chequers can be drawn as may be desired, and the lines rubbed out after the chequers are inked in. When part of the figure is broken away, there is no precise limit—that is, half a chequer more or less in either direction makes no difference. Put on the "line of section," A B, and then draw the section, observing that all points of the section correspond horizontally with all points on the line A B.

This drawing should be back-lined similarly to Fig. 176, but the lozenges being now projections instead of recesses the back-lines will be reversed. Upon a comparison of the two illustrations (p. 108 and p. 110) it will be seen that back-lining a drawing not only gives relief and variety to it, but helps also to explain the shape of the object represented.

The two following illustrations show a method of indicating the proportions of a structure by multiples of some unit. The unit in this case is the depth of the fillet in the base moulding of the pilaster (Fig. 178). A pilaster differs from a column in being a flat projection from a wall instead of a detached cylindrical construction, although both may be of the same general style and character. The size of the drawing depends upon the size adopted for the unit, which may here be one-eighth of an inch. By taking a larger or smaller length for the unit, the whole design will be proportionately enlarged or reduced without affecting the relationship of the parts to each other. Very much the same thing may be done by measuring a drawing with the wrong scale, and reading all the dimensions larger or smaller, as the case may be, from which the new drawing is constructed. The work given in Figs. 178 and 179 will be a very good test of ability; it requires a good eye and a steady hand to produce some of the parts, as any irregularity will be easily detected.

Begin with the plan of the pilaster (Fig. 178) and note that any measurements required which are not on that view may be

found on the elevation. The section lines in the plan show that it is, as plans very often are, a sectional plan—that is, not taken as it would appear when looking down above the summit of the structure, but from some intermediate height. The mitres in the plan at the external angles are produced by the junctions of the straight mouldings. The bottom of the plinth is not back-lined, because it would of necessity stand on something of larger area, and that would prevent a shadow being cast: it is shown standing on the ground. The semicircular flutings in the pilaster,

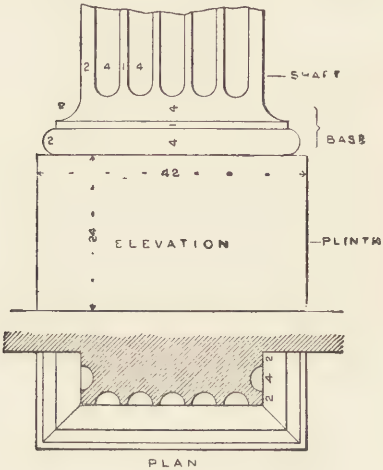


Fig. 178.—Fluted Pilaster.

4 units wide, are separated by narrow fillets, or flat surfaces 1 unit wide, and they are terminated at each end in the elevation by semicircles. The lower end only is shown, for want of space.

The column (Fig. 179) has similar flutes, say twenty in all, round the whole circumference, which will make it about 32 units in diameter. These should be set off in the plan and projected into elevation. At this point a great difference will be seen as compared with the pilaster (Fig. 178), although the flutes are in reality the same size, they are foreshortened, or turned sideways, towards the sides of the column, and appear much closer. This involves a special difficulty at the lower end of each flute, where

the semicircle will become elliptical, with one axis shortened more and more. The semi-ellipses will be all the same height as the semicircle, and the width will be given by the projection from plan. The curves themselves must be drawn very neatly by hand, so that their outline may be precisely similar to the other outlines. Sometimes an expert draughtsman may be found who can put them in with the bow-pen, but generally, if instruments are used, the curves will be steady and uniform, but badly shaped, while if put in by hand the curves will be unsteady and irregular in thickness, but better-shaped. In back-lining this

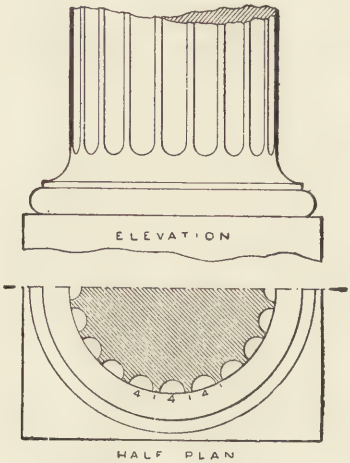


Fig. 179.—Fluted Column.

drawing, observe that the thickening of the curves is regulated by the 45° set-square, which shows where the line alters its character.

It should be remembered that, although the illustrations are printed when they appear in this book, yet they were all originally drawn by hand, and that any difference of quality is in favour of the original ; every effort should therefore be made to make drawings at least equal to the copy from which they are taken, and then good substantial progress may be expected.

CHAPTER VIII.

DRAWING TO SCALE AND PREPARING MAPS.

MECHANICAL drawings are usually made to a given scale, regulated by the relative size of the drawing paper as compared with the object to be represented, and it will be understood at once that only comparatively small objects can be drawn to actual size, as the draughtsman is limited by conditions of space and by considerations of convenience in handling. For example, in plans of buildings, maps, surveys, and in fact the great majority of the instances in which drawing is employed, it becomes necessary to reduce the representation of the object. In cases of minute mechanism it is desirable to increase the scale of them so as to show construction clearly.

The scale of a drawing is the proportion the representation bears to the actual object. A drawing is said to be "to scale," when all parts are in strict proportion to the original; and even rough sketches should be approximately to scale, or they will give a distorted representation which may convey a wrong impression. When a drawing is made to the same size as the object represented, it is said to be full size, while, if all the dimensions of the object are represented by distances on the drawing that are half full size, the drawing is said to be half full size. Since ordinary working drawings represent surfaces, not contents, the representation of an object with its length and breadth each reduced to, say, half the full dimensions would really be quarter full size regarding area represented. Lengths, not areas, are, however, measured, and the drawing is said to be half full size.

When it is proposed to produce a drawing of anything that measures more than two or three feet across, the drawing must almost of necessity be smaller than the object; and in order that the object may be reproduced faithfully, the reduction must be in every way proportionate. To whatever extent the representation of the object is diminished or in-

creased, the relative proportion of every part of the drawing to the corresponding part of the object must remain uniform throughout in order to produce a working drawing. In constructing a drawing either to a smaller or larger scale an artificial scale of measurement must be provided which shall bear the same relationship to standard length as the drawing is to bear to the real object.

The scale of a drawing, then, is the proportion lengths on the drawing bear to lengths on the object, and if a drawing measured 3 in. in any dimension, and it were known that that dimension as measured on the object was 1 ft., the scale of the drawing would evidently be 3 in. = 1 ft., or $\frac{3}{12} = \frac{1}{4}$ full size. All drawings, even when fully dimensioned, should have the scale stated, preferably under the title or heading, and if a detail, to show it more clearly, is drawn to a larger scale, the new scale should be mentioned near the detail drawing.

Scales are named according to the fraction they represent of the object to be drawn. For mechanical and building drawings, the following scales are generally used:—3 in. to a foot (Fig. 180), $1\frac{1}{2}$ in. to a foot, $\frac{3}{4}$ in. to a foot (Fig. 182). These scales are popular in the workshop, because they may be measured conveniently with an ordinary mechanic's rule; $\frac{1}{4}$ in., $\frac{1}{8}$ in., and $\frac{1}{16}$ in. representing 1 in. on the first, second, and third scales respectively. Again, 1 in. to the foot (Fig. 181) would be $\frac{1}{12}$ of the full-sized object, and the scales would be known as $\frac{1}{12}$, and so on. This method of naming the scales is general for students' work, but in the workshop the prevailing practice is to call the above scale "inch" and others "inch and a half," etc.

The scales shown in the accompanying examples are not reproduced to the full size marked upon them, owing to considerations of space; they should therefore be drawn again for use and practice. As an example, the construction of Fig. 180, a scale 3 in. to 1 ft $= \frac{1}{4}$, will be described. Three feet to this scale are shown, but the limits to which the scale is to be set out must depend on circumstances. Commence by drawing two lines 9 in. long and about $\frac{3}{16}$ in. or $\frac{1}{4}$ in. apart. Divide this length into 3-in. parts, each of which will represent a foot. The first division should then be further divided into twelve equal parts, each $\frac{3}{12}$ in. or $\frac{1}{4}$ in. long; these represent inches, and may be subdivided into half inches and quarter inches, the latter dimension on this

scale being represented by a length of $\frac{\frac{1}{4}}{4} = \frac{1}{16}$ in. The first foot, divided as just described, should be marked off in lengths of 3 in., as shown, starting with 12 in., and working forward to 0 in. The other divisions on the scale may be left open, as shown. The scale may be completed by drawing lines close to the top and bottom lengths, with alternate divisions marked by thick central lines, as shown (Fig. 180).

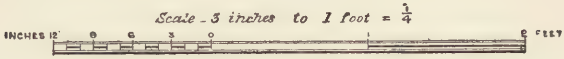


Fig. 180.—Quarter Scale.

There is a special reason for numbering the feet forward and the inches backward as shown. For instance: to measure 1 ft. 9 in., or 1′ 9″, open the compasses from the division marked 1 ft. to the division marked 9 in. If the inches had been marked in the same direction as the feet, and the feet had commenced at the left-hand end, as they are sometimes carelessly set off, then the scale would be found very confusing to measure from. It is better to number the inches 3, 6, 9 and 12 only than every one.

Fig. 181.—Twelfth Scale.

The proportion between the length of 1 ft. on the scale and 1 ft. of the actual object gives the ratio of the two things, and, stated as a fraction, gives the representative fraction. In the case of 3 in. to 1 ft. the representative fraction is $\frac{1}{4}$. This is always put on foreign drawings, so that the proportion may be understood by anyone unacquainted with the language; but on English drawings it is not generally found. It will be observed that the thick lines through the centre of the scale, are placed in alternate spaces. The first foot divided into inches is naturally heavy looking, so call this dark; then the next foot from 0 to 1 will be left light, and 1 to 2 will be made dark, and so on; then backwards in the same way with the inches dark and light alternately.

The next scale shown (Fig. 181) is suitable for larger objects or

for smaller drawings, the scale being generally selected according to the size of the object; it is set off similarly to the last, making it 6 in. long altogether, and dividing the first foot into inches. It may be marked off easily from a scale with twelfths of an inch, or the following construction may be readily adopted: At the commencement of the scale draw a line at an angle of, say, 30° to 45°; take the dividers and set them rather less than $\frac{1}{8}$ in. apart, then along this line prick off twelve divisions; join the last one

Fig. 182.—Forty-eighth Scale.

with the end of the first foot, and from the other points draw lines parallel to this one, which will give the twelfths of an inch required on the scale.

In the next example (Fig. 182), $\frac{1}{4}$ in. to 1 ft., the smallest dimension that can be conveniently marked is 3 in., so the first foot can be divided into four parts only, and in the final example of 10 ft. to 1 in., only feet can be shown. These will want extra care, and a fine point to the pencil. Fig. 183 shows a scale of 1 in. to 10 ft.

Fig. 183.—One-hundred-and-twentieth Scale.

Cardboard scales containing all the divisions generally required can now be obtained so cheaply that many scarcely ever use any others, but persons who have to work with them constantly prefer boxwood, while those who can afford it obtain ivory scales, because they are clean and lasting and, what is of more importance, their divisions are generally more accurate. For ordinary purposes a drawing will be good enough if constructed by such a scale, and the size written on, as 3 in. to 1 ft., or whatever the proportion may be between the drawing and the real object; but, for very accurate work, such as civil engineering or ordnance survey work, the scale should be constructed, or copied line for line, at the foot of the drawing, so that, as the paper shrinks or swells with the weather, the scale will vary exactly as the drawing does, and be a true measure for it.

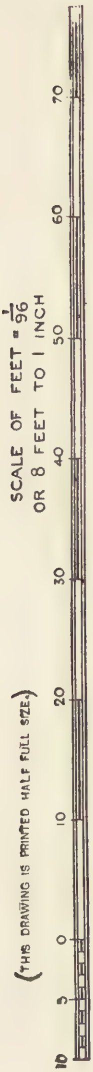


Fig. 184.—Ninety-sixth Scale.

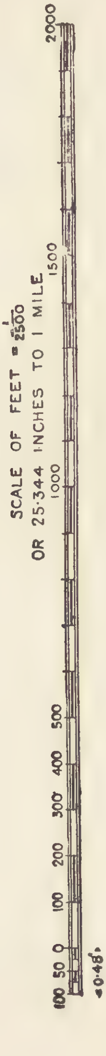


Fig. 185.—Two-thousand-five-hundredth Scale.

In working drawings of great importance it is usual to make a scale on the lower border line before commencing the work, so that the atmospheric changes may affect the drawing and the scale equally; but in ordinary work the scale is made after the drawing, simply for the purpose of ensuring that it is always at

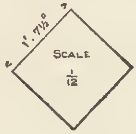


Fig. 186.—Square.

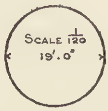


Fig. 187.—Circle.

Examples of Scale Drawings.

hand when the drawing is in use. These scales are made with slight variations according to their size, which will be evident on comparing the various illustrations given in this book as examples.

The correct method of plotting a scale upon a drawing may be illustrated by the accompanying examples, Fig. 184

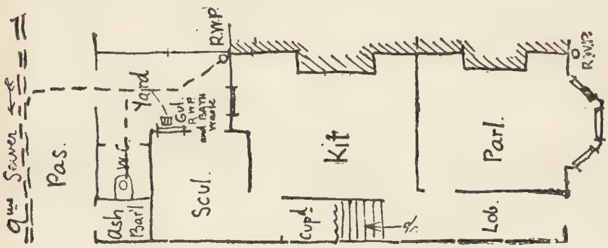


Fig. 188.—Sketch Plan of a House.

showing a scale plotted to $\frac{1}{8}$ in. to a foot, and showing a length of 70 ft., and Fig. 185 a scale plotted to $\frac{1}{2500}$ (Ordnance scale), showing a length of 2,000 ft. Each scale should be plotted with a fractional part on the left of zero, so that distances like 23 ft. on the first scale and 375 ft. on the second scale may be measured by placing the dividers on the respective figures. The accompanying scales are reduced to half size for printing.

In addition to scales, a square (Fig. 186) and a circle (Fig. 187) are shown, and as an exercise each is to be drawn to the scale

mentioned upon it. Scales in common use for architectural drawing are $\frac{1}{8}$ in. and $\frac{1}{4}$ in. to 1 ft. for plans, elevations, and sections, and $\frac{3}{4}$ in., 1 in., $1\frac{1}{2}$ in., and 3 in. to 1 ft. for details, and

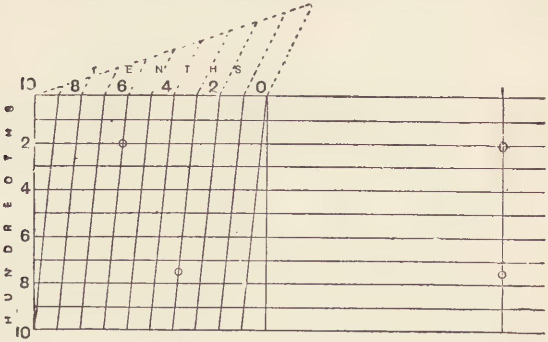


Fig. 189.—Diagonal Scale for Accurate Measurements.

full size for mouldings. In machine drawing, $\frac{1}{2}$ in., 1 in., $1\frac{1}{2}$ in., and 3 in. to 1 ft. for general plans; $1\frac{1}{2}$ in. and 3 in., half size and full size, for details. In other branches smaller scales are common, as 100 ft., 50 ft., 40 ft., 20 ft., and 10 ft. to 1 in. in civil

Fig. 190.—Scale Showing Tenths and Hundredths.

engineering; 88 ft. to 1 in., 3 chains to 1 in., etc., in land surveying. Sometimes, in order to get an even representative fraction, some peculiar scales are used for maps—for example, 25·344 in. to 1 mile is used because it gives the representative fraction of $\frac{1}{2500}$, as shown in Figs. 185 and 193.

Drawings that often come under notice include plans of houses. These are generally drawn $\frac{1}{96}$ of full size—that is, on a scale of $\frac{1}{8}$ in. to 1 ft. Upon this scale it is possible to show the size and shape of every room, the position of every door, fireplace, and window, stairs and landings, slopstone, gully, bath, water-closet, cupboard, down-pipe, gutter, etc.,

etc. A drawing of this kind, with all the thicknesses of walls, etc., shown accurately, takes some time to produce; but for note-taking elaboration is hardly necessary; but a rapid sketch of a house, as shown at Fig. 188, would be intelligible to anyone familiar with buildings.

Plans of land are drawn to a small scale, from which the inch marks are necessarily omitted, and in which the feet, when they are represented at all, have their ciphers left out. For large tracts of land a scale of 6 in. to the mile is often used; for smaller portions, a scale of 1 in. to a chain is commonly employed.

In cases, where fine divisions are required, the diagonal scale is generally adopted. In drawing one for the first time, it is better to make it a large one, as then the construction can be followed more readily; say, the illustration shown by Fig. 189 is first drawn with 5 in. for the unit. The division of the first space on the upper line into ten equal parts may be made by stepping ten times with the spring dividers, or geometrically, as shown, and must be repeated at the bottom. Similar divisions are then to be made on the left-hand vertical line, all the horizontal lines drawn through, and the vertical lines at each 5 in. The diagonal lines must next be put in, the first of them reaching from zero on the top line to the end of the first division on the bottom line, and the others parallel to it, so that, as each diagonal crosses a horizontal line, it leaves a space increasing by hundredths of the unit.

In the third line down will be found two small circles, the distance from centre to centre being 1·62, measured thus: on the right from the zero line is one unit, the sixth diagonal line on the left from the zero shows six-tenths, and the second line down from the top shows two-hundredths contained between the zero line and the first diagonal. The two circles in the third space from the bottom represent 1·375, being midway between 1·37 and 1·38. The smaller scale, illustrated by Fig. 190, is like those that appear upon the machine-made scales, and will now be understood without further description.

In the case of a map or plan, for example, the artificial scale may have an actual length of, say, 5 in., which at the same time represent a distance of ten miles in the drawing.

In this instance the scale would be divided into ten equal parts, each indicating miles, while by subdividing one of these divisions into eight equal parts, furlongs would be represented. Here an actual length of half an inch is understood to represent one mile, and the map or plan would be described as being drawn to a scale of half an inch to the mile. Another way in which this fact may be stated is this:—The number of half inches in a mile is $1760 \times 3 \times 12 \times 2 = 126,720$; and as this number of half-inches is represented by one half-inch, it is evident that the drawing is

Fig. 191.—Scale $\frac{1}{10560}$: 1 in. = 880 ft.; 6 in. = 1 mile.

only $\frac{1}{126720}$ the size of the real object it is intended to show. This sum $\frac{1}{126720}$ is known as the representative fraction of the scale, and sometimes is used to indicate any particular scale instead of the previous expression.

The value of scale drawings is particularly shown in the maps issued from time to time by the Ordnance Survey. These have not all been drawn to one uniform scale, it having always happened that before the map of the whole country could be completed upon any one scale, the discovery of some defect or the suggestion of some improvement has induced the Department to begin afresh upon a different scale.

Speaking generally, the whole country has been mapped out upon a scale of 1 inch to the mile, and also on a scale of 6 inches to the mile (see Fig. 191). Maps on this scale are too small to represent anything but the barest outlines of very large schemes, and here they need not be further described.

Fig. 192.—Scale $\frac{1}{1056}$: 1 in. = 88 ft. ; 10 ft. = 1 mile.

Later, the Department issued maps of the principal towns on a scale of 10 feet to the mile, or 1 inch to 88 feet (see Fig. 192). This map, though small, was very useful. It was very clearly printed from engraved plates, and was a work of art as compared with the maps issued at the present time. This scale, however, has been abandoned, and the Department now publish town maps on the following scales —namely, 25·344 inches to the mile, or 1 inch to 208·33 feet or $\frac{1}{2500}$ full size (Fig. 193), and 10·56 feet to the mile, or 1 inch to 41·66 feet, or $\frac{1}{500}$ full size (Fig. 194). This last

map is exceedingly useful, the scale being large enough to show upon the map man-holes, sewer ventilators, gullies, lamps, etc. ; and by its aid can be laid down schemes for the drainage of even a single house. The sheets of these maps measure about 38 inches by 25 inches, and can be purchased plain or coloured.

The accompanying illustration shows a small portion of

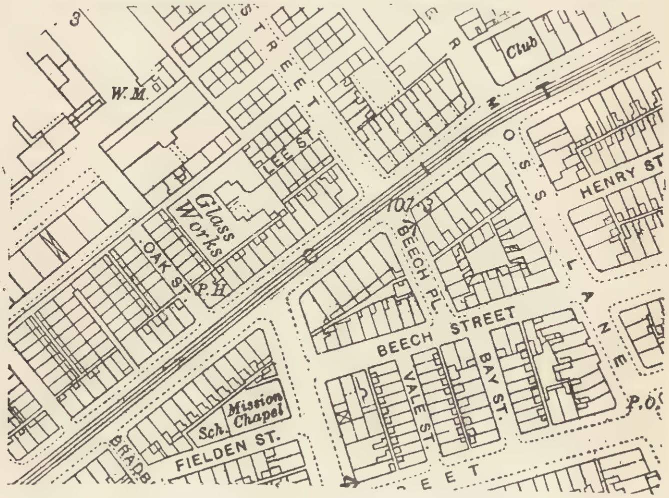


Fig. 193.—Scale $\frac{1}{1500}$: 1 in. = 208·33 ft.; 25·344 in. = 1 mile.

the $\frac{1}{500}$ Ordnance map. At the corner of the house a bench mark has been cut (these are usually about 1 ft. 6 in. above the surface of the ground), and the figures indicate that the point is at a height of 89·55 ft. above Ordnance datum. The Ordnance datum is an imaginary horizontal plane extending over the whole country at the same height as the average mean level of the sea at Liverpool. This datum was fixed by the surveyors of the Ordnance Department, and the levels of districts are marked on the Ordnance maps as being so many feet above the Ordnance datum; that is, above the average sea-level at Liverpool. The figure in the roadway indicates that the road at that point is about 87·7 ft. above the datum, the second place of decimals not being given.

Figs. 191 to 194 illustrate plans of streets, and these drawings show what the street would look like as seen from a balloon. All these are drawn to scale so that the lengths and widths can be measured from the plan. Kerb-lines are usually represented by dotted lines. Ordinary colours used for the roadway are sepia or pale indigo; footpaths, pale burnt sienna; buildings, crimson lake or indigo. Lines of sewers are shown by blue lines or thick black lines.

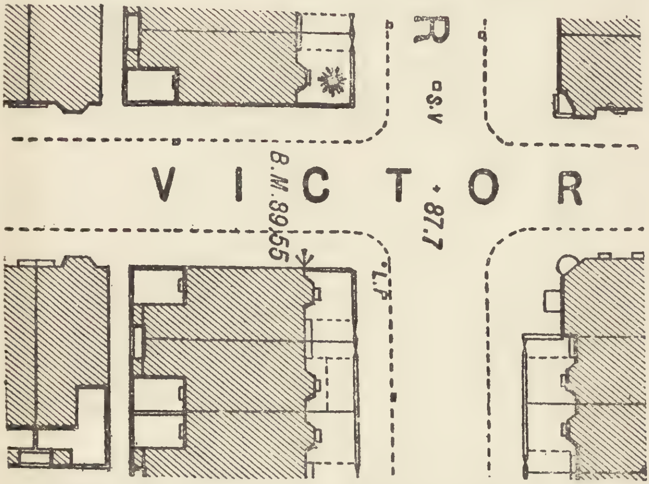


Fig. 194.—Scale $\frac{1}{500}$: 1 in. = 41·66 ft.; 10·56 ft. = 1 mile.

A drawing showing what the street would look like if all one side of the street were excavated away, the spectator looking squarely at the face of the excavation, would be called a section. The drawing would then show the setts at the top, the ballast underneath, earth beneath that again, and, lower down still, the gas and water mains and sewers. In sections for new streets that are to be made, the present surface of the ground is indicated by a more or less crooked line. The finished level and the formation level are generally indicated by coloured lines, and the sewer is shown at its proper depth and inclination.

CHAPTER IX.

COLOURING DRAWINGS.

Colour is a very considerable aid to "reading" a drawing, particularly when different materials occur adjacent to each other. Architectural and mechanical drawings are intended for use rather than for decoration, and the colouring is used chiefly to denote the different kinds of material, but there is no valid reason why a drawing should not be neatly finished as well as accurate in draughtmanship and colouring. The colours not only emphasise the separate pieces by contrast, but custom has decided that certain materials shall be represented by certain colours, some being almost the natural tint of the material, and others purely conventional. It is more important that parts in section should be coloured than parts in elevation; a section is always an imaginary cut, and the colour is put upon the cut surface because otherwise it is not so easy to recognise as it would be in the elevation. A true section can be seen only by "mental vision," while an elevation is subject to ordinary vision. The list on p. 138 gives selections from the practice of the best engineers' and architects' offices, and is the standard adopted by many. Some of the colours may be replaced by less expensive ones, such as yellow ochre for Roman ochre, neutral tint for Payne's grey, or neutral tint with a little crimson lake for violet carmine.

The extremes of good and bad drawing and colouring are commonly to be found in architects' offices as contrasted with civil engineers' work. Some of the faults are running all lines beyond the proper junction, making them also unnecessarily broken and very thick, ruling ink lines close above and below and even through the printing, making letters of such fantastic shapes that reading is difficult, and even extending the same style to the dimension figures, using crimson lake in colouring elevations instead of one of the numerous reds having the natural tint of red bricks or

tiles, using Prussian blue for anything but wrought iron, etc. A detail drawing sent out from an architect's office, that showed a wrought-iron girder resting on a cast-iron column standing on a stone base, had all the parts coloured with a full tint of Prussian blue on the score of custom, so that the use of colour at all was of no advantage whatever in distinguishing the material; moreover, Prussian blue is a harsh colour at the best of times, and should be avoided whenever possible. Many draughtsmen have a natural talent for using suitable colours, and putting them on in a suitable manner, but others must go through the drudgery of careful

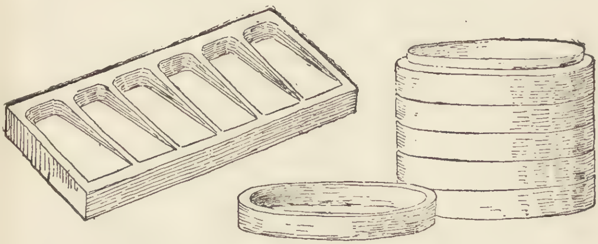


Fig. 195.—Slant and Saucers for Colours.

practice according to rule. A perfectly uniform tint such as desired on an engineer's drawing is not required on an architect's drawing, and still less on that for use by a builder; but unless the draughtsman learns first to lay on a flat and uniform wash of any tint, he is not likely to be able to put on an appropriate rough tint. For water-colour sketching a flat tile with shallow recesses is suitable for mixing the colours, but this is quite unsuited for a draughtsman's use. He should invariably use the nests of round saucers fitting one on the other, as shown by Fig. 195, of a size to hold as much colour as would be required to completely finish the colouring of any one material on one sheet. The saucers should be kept covered while in use, and washed out when done with. The lightest tints should, as a rule, be put on first, and the brush should always be of ample size. Colour brushes should be kept scrupulously clean, never put in the mouth, always washed after using, the sur-

plus moisture shaken out, and then put away in the box and not laid on a dusty shelf to dry.

In giving on p. 138 a list of the colours used in architectural and mechanical drawings, it may be said that the colours adopted vary according to circumstances, and it is difficult to lay down general rules. The practice in some

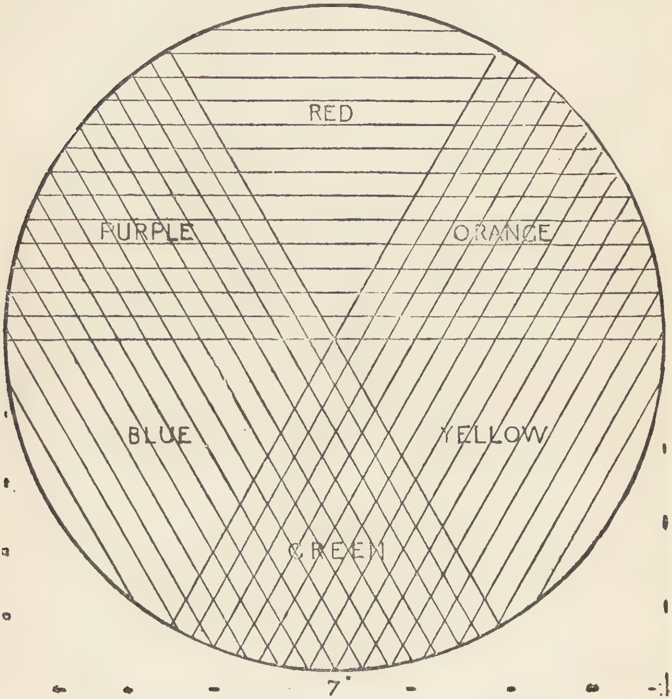


Fig. 196.—Primary Colours and Secondary Tints.

good offices is to use a very pale sepia for York stone in elevation, pale Payne's grey for Portland or Bath stone, pale indigo for granite with ink dots, and darker tints of the same colours for the sections. Architects, who ought as a body to have an eye for colour, sometimes offend by using harsh and unnecessary colours on their drawings.

Blue in some form or other is much used by architects to represent stone, but it should be used very sparingly, so as to resemble the natural tint of the stone rather than the conventional representation. For a red sandstone, a pale tint of light red, Indian red, Venetian red, or burnt ochre might be used, depending upon the general elevation colour. For cement in any form in elevations, pale Indian ink or pale Payne's grey is generally used, with or without dots and markings. Windows may be coloured with black Indian ink, or washed Prussian blue, Prussian green, or Payne's grey, according to circumstances. A plain tint all over is the simplest, but a good artistic effect may be obtained with the exercise of a little skill.

A little practice in the laying of colours one over another will be useful for impressing on the memory the general effect of combination and also a knowledge of the primary colours and their secondaries. Nearly all water-colours are transparent, and a medium tint of any one colour, if laid over another after it is dry, will allow the first colour to show through. A more intimate combination may be made by mixing the colours together in the same palette and putting them on with the brush in one operation.

It should be noted that a draughtsman never speaks of "painting" his drawing; the term is frequently misused, but it should be colouring or tinting.

If a circle (Fig. 196) and a square (Fig. 197) be set out and coloured as marked in the accompanying diagrams, some of the results of combination may be easily produced. Prepare in separate saucers some Prussian blue, crimson lake, and gamboge to medium tints of about equal intensity; these are the so-called primary colours. In Fig. 196 the half-circle marked purple, red, and orange should be coloured first with a tint of crimson lake; as soon as it is dry the half-circle marked purple, blue, and green should be covered with a tint of Prussian blue; and the half-circle marked orange, yellow, and green should be covered lastly with a fairly strong tint of gamboge. Where the pairs of colours are superposed, the secondary tints of purple, orange, and green will be found to have been made by the combination. Each section of colour in the circle will be complementary to the one opposite it—that is, it will be in extreme contrast,

and it is a physiological fact that when the eye is fatigued by looking at one of them it will be rested by looking at that opposite.

If a square of 7 in. side be divided into parallel columns

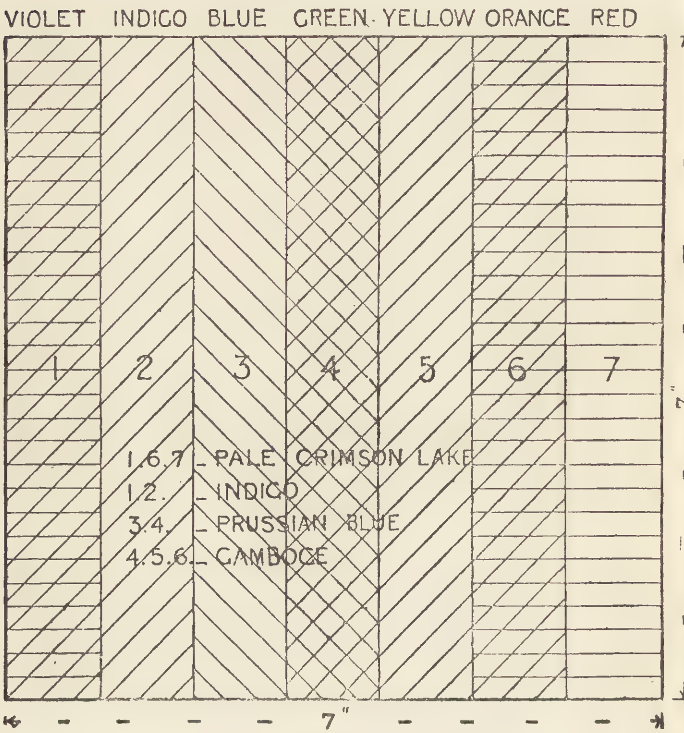


Fig. 197.—Colours of the Spectrum.

of 1 in. each and numbered as shown in Fig. 197, and equal tints of crimson lake, indigo, Prussian blue, and gamboge be prepared, the various rainbow colours named upon the columns may approximately be produced as follows: Tint the columns numbered 1, 6, and 7 with crimson lake, 1 and 2 with indigo, 3 and 4 with Prussian blue, and 4, 5, and 6 with

gamboge. The lines drawn across the diagrams show the extent of each colour. If care be taken to put on even tints and not to go beyond the outline, this recreation of colouring will enable the practical work to be carried out efficiently.

In practical colouring for draughtsmen's work (see Fig. 197) the first point to note is that the colour in any one space must not overlap the boundaries; it must be of the right tint, and laid on perfectly flat or uniform. To do this requires skill that can only be acquired by practice. Use a set of colour saucers, in one of them put a little clean water, but not much, as a teaspoonful will colour a square foot; rub in it gently the end of a hard-cake colour, until it is dark enough, and then stand the colour up on its dry end. Use a brush about $\frac{1}{4}$ in. diameter and $\frac{3}{4}$ in. long, rinse it in clean water, and pass it through the saucer to mix the colour until it looks perfectly uniform, without points or marks near the edges, and above all without chips in it.

Wipe the brush lightly on the edge of the saucer to remove the surplus colour, and hold it as described for a lead pencil when about to draw a vertical line; commence at the top left hand of the space to be coloured; pass the brush downwards, then along the top, then down by short strokes from the top to the length of the first stroke, and so carry the colour downwards for the whole width, finishing at the bottom right-hand corner.

To produce good and uniform colouring, never damp the paper before commencing, re-fill the brush often, gently wiping it on the edge of the saucer each time. The margin of the colour must not dry before the next stroke reaches it, and a part once coloured must never be retouched, even though it looks uneven. Retouching is a fruitful source of failure; for colour, looking uneven when wet, may dry even, but if touched again when partially dried it is certain to show uneven when dry.

There is an advantage in having plenty of colour in the brush, but when nearing the bottom boundary the amount must be reduced, so that there is not a pool left at the lower corner. By regulating the amount of colour any slight excess may be picked up with the brush by simply raising it slowly, point last, from the corner. The brush should not be wiped in any way, but simply washed in clean water when

done with, or before use with another colour. It will soon be found that with a given amount of colour in the brush more or less of it may be left behind as the brush is allowed to trail or is used sideways, and it is by unconscious adjustments of this kind that a good colourist produces uniform results.

It is useful to remember that sections of materials are always coloured with a dark tint, but the term dark is only relative; for instance, with dark Prussian blue for wrought-iron, it should be quite easy to read ordinary dimension figures. Dark tints are more difficult to lay on evenly than light ones, but the same method is adopted. Another source of difficulty in sections is that to produce the best results a very narrow white margin should be left uncoloured on the top and left of each portion, where rays of light from the top left-hand corner of the paper would strike upon them. This custom enables the number of plates to be more readily seen in large girders, and makes all sections more effective.

The colours for tinting woodwork on a drawing may either be plain, or, if time and other circumstances permit, may be laid on in imitation of the natural grain, although, to a certain extent, all colouring on mechanical and architectural drawings is conventional. For the plain tints the following may be used: Fir and deal used in the rough, raw sienna or gamboge; for the same if wrought and for pitch pine, burnt sienna; for oak, burnt umber or sepia; for mahogany, light red. If graining is to be attempted, each kind of wood requires three gradations of colour for elevation and section.

Suppose an example be attempted of wrought fir or deal as in the accompanying diagram, a pale tint of burnt sienna must be laid uniformly over the front and side elevations (Figs. 198 and 199), including the splintered ends, then a darker tint must be mixed and laid uniformly over the end grain and cross-section pieces. This darker tint will be the one used for the graining on the front and side elevations, and in mixing this colour it would be well to compare a piece of the actual wood represented, as the accompanying illustration, as printed, is necessarily much too black to give the right effect. Two brushes will be needed, one for the colour and one with plain water for softening the inner edge of the graining lines as they are put on. The water brush

Fig. 198.—Front Elevation Showing Deal or Fir.

Fig. 199.—Side Elevation Showing Deal or Fir.

Fig. 201.—End Grain.

should be wiped on the edge of the glass or gallipòt containing clean water, leaving the brush wet, but not fully charged, and every minute or two it must be rinsed in the water to keep it clean.

The so-called heart part in a board showing good grain appears in wider pieces than the other part, and more filled up at the ends, while the grain towards the edge appears narrower and in lines closer together. The heart grain also gets more and more pointed as it leaves the central piece, until it runs out into nearly straight lines or widens again into a fresh piece of heart. The outer edge of the graining in elevation should be sharp and clear, while the inner edges

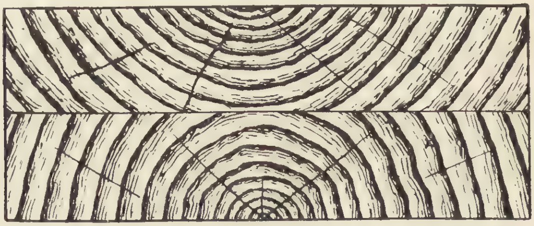


Fig. 200.—End Grain.

should be softened off with the water brush in a graduated tint, so that it shall be difficult to see where the colour ends. In doing this, care must be taken not to overlap the sharp edge of the inner line. It is rather better to work from the middle of the board outwards than to put in the outer grain first. In the side elevation (Fig. 199) the grain is shown by single lines slightly waved, and all softened on the lower edge.

The elevations having been completed, the colour should now be mixed in its third degree of intensity for the parts showing end grain or cross section (Figs. 200 and 201). No distinction is made between these two conditions. The rings showing the annual growth of the tree may be lightly pencilled if desired, but it is just as well to proceed at once with the colour, making the rings dark on the outer edge, and softening the inner edge with the water brush. After the rings are dry, about three radial lines may be put in at

random without any softening. These may look like heart shakes, but they are really to give more effect and to relieve the monotony of the circles.

There are other methods of indicating section parts of woodwork on small drawings; the ordinary way is simply to put in diagonal lines of colour with the brush, reversing the direction of adjacent pieces. Engineers sometimes rule in the colour with the drawing pen, using alternately thick and thin lines. Architects often colour round inside the outline, and then put diagonal lines across. Samples of all these methods are shown in Fig. 202, as nearly as can be given in print, with black ink.

Oak differs very much from fir and deal in the nature of its grain, and is much more difficult to represent. In most cases it will be sufficient to use a plain tint of burnt umber or sepia, light for elevation (Figs. 203 and 204), and dark for section (Figs. 205 and 206), but there are always some aspiring draughtsmen who want to get the best result from their labour, and they may be glad of a few hints. The difference of grain will be better understood after a short description of the trees themselves. Fir and deal have a soft, straight grain with comparatively wide and regular annual rings more or less strongly marked, darker on the outer edge of each, and with the medullary rays not showing. Oak has narrow, close, and irregular annual rings, with the medullary rays, or felt, or flower, or silver grain strongly marked both on the end and face. The medullary rays are hard plates of flattened cells more or less radial, but running somewhat irregularly in the length of the tree, so that when a board is cut to show the "flower" they appear as small hard slabs of a lighter colour and solid texture, averaging perhaps $1\frac{1}{2}$ in. by $\frac{1}{4}$ in. broader in the middle and slightly curved.

In order to show these rays on a drawing in water-colours the surface must be tinted with pale burnt umber, leaving the light spaces, and one side of these may be softened off with the water brush to imitate nature more closely. The colour then being mixed a little darker, the rest of the graining may be put on, which is little more than a series of broken lines without softening. The same colour will be used for the underneath tint on the end grain; and then,

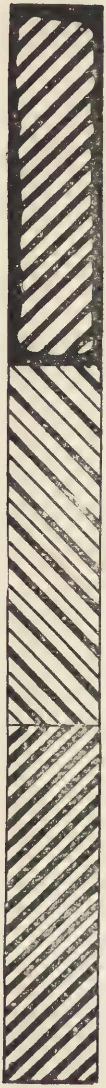


Fig. 202.—Various Cross Sections for Fir.

Fig. 203.—Front Elevation Showing Oak.

Fig. 204.—Side Elevation Showing Oak.

mixing it still darker and using a fine-pointed brush, the end grain may be put on in thin dark lines, broken frequently, and placed rather close together. When this is

Fig. 205.—End Grain Oak.

done the medullary rays may be put on with the same brush and colour, keeping them fairly radial, but somewhat

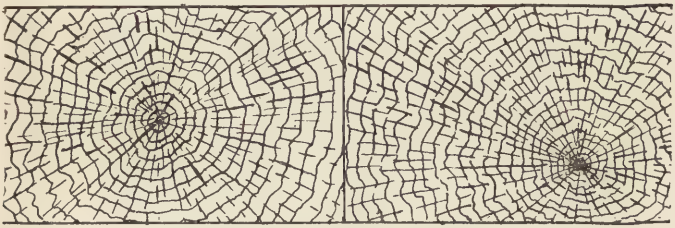


Fig. 206.—End Grain Oak.

irregular and broken, and adding other lines as the work progresses towards the outer edge. The smaller pieces of

ORDINARY. ENGINEERS. ARCHITECTS.

Fig. 207.—Various Cross Sections for Oak.

oak are coloured (as shown by Fig. 207) conventionally in the same way as described for fir and deal, the only difference being that burnt umber is used for oak.

DISTINCTIVE COLOURS GENERALLY USED IN ARCHITECTURAL AND MECHANICAL DRAWING.

Banks (Steep).—Shaded with graduated warm sepia, darkest at top of bank, vertical hill-shading in Indian ink or dark sepia.

Brass.—Gamboge with yellow ochre or burnt sienna.

Bricks (Blue).—Elevation, indigo and Indian ink; section, indigo. (Red).—Elevation, light red (pale); section, Indian red (dark).

Brickwork (New).—Elevation, Roman ochre; section, crimson lake. (Old).—Elevation, Indian ink (pale); section, Indian ink (dark).

Buildings (Brick or Stone).—Crimson lake. (Wood).—Sepia.

Cast Iron.—Payne's grey; neutral tint.

Chain.—Elevation, Prussian blue (dot and stroke); section, no colour.

Concrete.—Sepia with black marks; or indigo, or Payne's grey with black marks and small light spots left.

Copper.—Gamboge with lake; elevation, crimson lake and burnt sienna; section, crimson lake and burnt sienna (dark).

Earth.—Burnt umber or warm sepia, left jagged at edges; or sepia, light and dark.

Electric-bell Wires.—Yellow.

Fields and Vacant Lands.—White.

Fir and Deal (rough).—Elevation, burnt sienna or gamboge; section, burnt sienna (edged round and hatched).

Fir and Deal (wrought).—Elevation, burnt sienna (pale); section, burnt sienna (dark rings).

Footpaths (Flagged).—Yellow ochre.

Glass.—Green; Prussian blue; neutral tint.

Glass Roofs.—Cross-hatching of Prussian blue.

Granite.—Purple madder; pale Indian ink.

Greenheart.—Elevation, indigo and gamboge; section, indigo and gamboge (dark).

Gun-metal.—Elevation, Indian yellow; section, Indian yellow (dark).

Lead.—Indigo; indigo with Indian ink.

Leather.—Elevation, burnt umber (very pale); section, burnt umber (dark).

Mahogany.—Elevation, light red and burnt sienna; section, light red and burnt sienna (dark).

Meadows and Cultivated Grass.—Prussian green; Hooker's green.

Oak.—Elevation, burnt umber (pale); section, burnt umber (dark).

Pipes (Cold-water).—Prussian blue. (Gas).—Indigo with lake. (Hot-water).—Crimson lake. (Rain-water).—Elevation, Prussian blue (outline); section, Prussian blue (outline). (Soil).—Elevation, burnt sienna; section, burnt sienna (outline).

Plaster.—Payne's grey. Plaster and Cement.—Elevation, Indian ink (pale); section, Indian ink (dark).

Railways.—Neutral tint between the rails of each track.

Rope.—Elevation, burnt sienna (dot and stroke); section, no colour.

Rosewood.—Burnt sienna with lake.

Sewers and Drains.—Prussian blue.

Skies (in perspectives).—Cobalt blue.

Slate.—Elevation, Payne's grey; section, Payne's grey (dark).

Steel.—Elevation, violet carmine (very pale); section, violet carmine (dark); or indigo with a little lake.

Stone.—Yellow ochre; gamboge with Indian red and burnt umber; sepia; Prussian blue. Representing stone in section by Prussian blue is to be avoided, though in common use. Prussian blue should be retained entirely for wrought-iron work.

Stone Dressings.—Elevation, French blue (very pale) section French blue (dark).

Streets (Paved).—Neutral tint.

Timber (Existing).—Elevation, Indian ink (pale); section Indian ink (etched).

Tubes (Speaking).—Green.

Water.—Elevation, Prussian blue (washed); section, Prussian blue (lines). Water may have graduated blue edges.

Windows Inside.—Elevation, French blue (pale); section, Hooker's green, No. 2 (dark).

Windows Outside.—Elevation, Payne's grey (dark); section, Hooker's green, No. 2 (dark).

Wrought-iron (Bright).—Elevation, Prussian blue (very pale); section, Prussian blue (dark). (Rough).—Payne's grey.

York and Soft Stone.—Elevation, sepia (very pale); section, sepia.

Zinc.—Elevation, French blue (very pale); section, French blue (dark).

CHAPTER X.

MAKING A DRAWING.

ALL the general principles upon which the drawings are constructed have been dealt with, and any attentive reader who has worked out enlarged copies of the diagrams will have made very substantial progress towards becoming a skilled draughtsman.

In commencing a drawing the first thing is to decide whereabouts on the paper the various elevations, plans, and sections will be disposed, and of what size they can be drawn, so as to find sufficient room for them and their descriptions. The scale having been once determined, it is well to make a pencil memorandum of it in one corner of the margin, for it often happens that a drawing has to be left uncompleted for several days, when the note will save the trouble of trying over various scales, in case the original one has been forgotten. The plans of a building or piece of machinery are usually placed directly above or below the elevations, so that the various features can be projected from one to the other by the use of the T square. End elevations are placed to the right or left of the main elevation, in accordance with the side which they represent.

There is one simple and general rule which is to be observed in making any drawing, and that is to commence with the main dimensions first, and draw them in their correct positions before filling in the smaller details. If this be not attended to, and a number of small details are added one to another without first setting out the total length they are to occupy, it will generally be found that some slight errors in each measurement which it is impossible to avoid have accumulated so as to make a decided discrepancy.

As an example, suppose a front elevation of a building has to be set out, containing a doorway in the centre, with three windows on each side. When the widths and spaces are each set out separately, commencing at one end, and measuring each from the termination of the last, it will be seen that, although each measurement may be within one fraction of the correct

dimension, the total may be as much as fifteen fractions in error. The correct method would be to set off first the total length of the building, then to find the centre and set off the width of the doorway, and afterwards to fill in the windows and spaces.

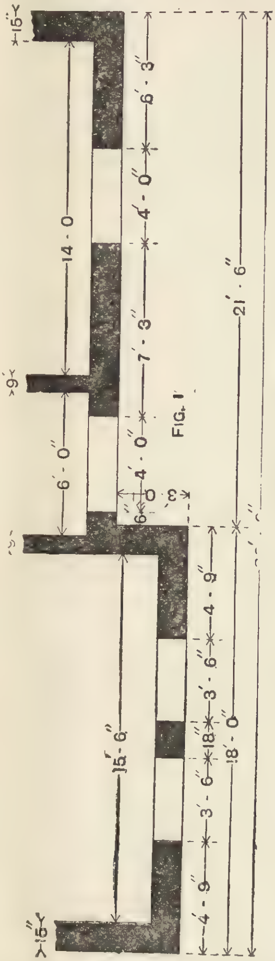


Fig. 208.—Method of Marking Measurements.

Suppose Fig. 208 to be the plan of the front of a small villa. An "over-all" measurement of 39′—6″ should first be put on the drawing, and then be subdivided as shown, into 18′—0″ for the projecting portion and 21′—6″ for the recessed part. These measurements should be again subdivided, showing the lengths of brickwork, widths of openings, etc.; and a line of measurements inside gives the thicknesses of the walls, dimensions of rooms, etc. The distance that the part projects should also be noted as shown by 3′—0″. The inside measurements and the smaller dimensions should exactly agree with the "over-all" measurement given.

In drawing pencil lines they should always be drawn longer than the actual length of the line to be inked in, so that the exact point of intersection with other lines can be better seen. When the drawing has been inked in these extra lengths, of course, have to be cleaned off with indiarubber, as well as a great many other pencil lines which are necessary in the process of making the drawing, but which form no part of the finished draw-

ing. These "construction lines," as they are called, should be drawn as lightly as possible, so as to be easily removed without greatly damaging the surface of the paper. When drawing circles or arcs of circles with the compasses, a little pencil mark should be made round the centre-point, so that it can be found without any trouble when it is desired to draw it in ink. It is useless to draw in pencil every one of a long series of circles or arcs which are all alike; it will be more expeditious to mark the centres only after drawing the first one or two, for in the inking-in of the drawing, when the compasses are once set to the correct radius, the centres will be all that is required to draw them in full.

Every working drawing, when it leaves the draughtsman should be carefully and completely figured. A little time spent thus in figuring the builder's tracings so that the sizes of window openings, thicknesses of walls, etc., are clearly stated, will save the architect and clerk of works worry and inconvenience while the building is in progress. It is well for the lines along which the measurements are given to be drawn in colour. The ticks ′ and ″, those well-known signs for feet and inches, should be clearly shown, and a short dash between the feet and inches keeps the figures clearly apart as 6′—10″. A measurement of feet only should always have a cipher in the place of the inches, as 25′—0″. The arrow-heads, showing where the dimensions apply, should always be carefully and clearly marked thus: |←—10′-6″—→|.

Vertical measurements showing the height of rooms are best figured from floor to floor, never from floor to ceiling, but allowance should be made for the depth of the floor. The height of the windows should always be figured from the top of the sill to the underside of the head, and their position from the level of the floor to the top of the sill, this giving exactly the opening in the brickwork. If a drawing is carefully figured on the lines here indicated, it is much easier for the workmen to carry out the work correctly, and much labour in superintending is saved to the architect and contractor.

The next example for practice shows that some substantial progress has been made, and, while apparently working only on detached fragments in previous examples, a framework of knowledge and skill has been built up that can now be applied to practical uses.

Fig. 209 shows a small plan of an irregular piece of ground, bounded by straight lines and containing a cottage. This would be called a block plan, because the cottage is shown as a solid block—without details. It will be seen that every part of the plan is "triangulated," which means that each junction point has three dimensions to fix it, upon the same principle as large surveys are carried out.

This block plan of a cottage and grounds is intended for practice in drawing to a scale of 1 in. to 8 ft. Before commencing, ascertain the extreme length and height of the drawing, so

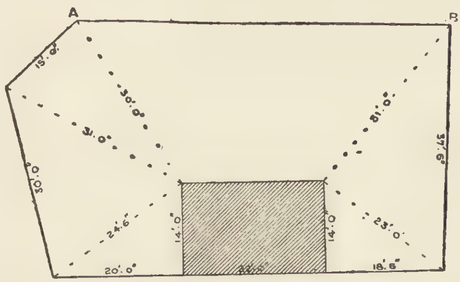


Fig. 209.—Block Plan of Building and Site.

that the base line may be drawn in a convenient position upon the paper. Mark off along the base the lengths shown, and, with the extreme left of the line as a centre, mark with the compasses an arc of radius on the scale equal to 24 ft. 6 in. Similarly, with the mark 20 ft. from the left-hand end of the base line as centre, strike an arc of 14 ft. radius to cut the first arc, and the intersection of these arcs will fix one corner of the cottage. The right end of the line may be dealt with similarly, and the plan of the cottage completed with straight lines. Then from the left end of the base line strike an arc of 30 ft. radius, and from that corner of the cottage first found strike arcs of 31 ft. and 30 ft. radius, the 31 ft. radius cutting the first 30 ft. radius, and the intersection of these arcs will fix one of the angular points of the garden ground. From this angular point an arc of 15 ft. radius, may be struck; this, intersecting the second 30 ft. radius, will obtain the point A. The point B may be found similarly, and the plan finished by connecting A to B by a straight

line. The length A B, measured on the scale, should indicate 58 ft. 6 in. on an accurate drawing.

In practically measuring any piece of ground for the purpose of making a plan, there are one or two principles to bear in mind —first, the lines upon which the measurements are taken must be so arranged that it is not possible to make a mistake without discovering it in "plotting" or "drawing to scale." For instance, in the present case, if the measurement 30 ft. from A had been taken as 29 ft., then A B would scale shorter than 58 ft. 6 in., and thus it would be known that there was some error; and any other wrong dimension would, in the same way, distort the figure, so that the last line would not work in correctly. Another principle is that where several small measurements occur in one line, as

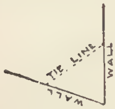


Fig. 210.—Measuring an Angle.

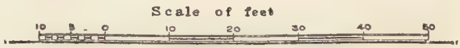


Fig. 211.—Scale for Plan shown at Fig. 209.

piers and panels in a wall, a general dimension over all should be given, which should agree with the sum of the separate measurements. Thus the over-all dimension of the base line in Fig. 209 might have been shown, as it is the sum of the running dimensions, or 20 ft. + 32 ft. + 18 ft. 6 in. = 70 ft 6 in. Sometimes, in order to obtain the angle one wall makes with another, a special measurement is taken across the angle at a little distance from the junction, instead of taking the whole length and the distance between the ends. This is shown in Fig. 210.

The cottage may be covered, as here illustrated, with lines at an angle of 45°, called "hatching," to show that it is a building. If the scale were smaller, it might be covered over solid with a tint of dark Indian ink; and if the drawing were coloured, it would be tinted with crimson lake, while the garden ground might be coloured green.

Now make a neat scale of feet (Fig. 211) on the lower border line, showing 10 ft. by units and 50 ft. by tens, the units being numbered backwards.

It is a good rule as far as possible to limit the writing on a drawing; but, whenever writing is done, it must, first of all, be

readable, and with this object it is well to use plain block letters for headings, and italics for descriptive notes. Architects very often obscure their printing on plans by inventing new letters, making them of microscopical size, placing them between ink lines, and finally skewering them with another line through the

A B C D E F G H I J K L M N O
P Q R S T U V W X Y Z &c.

Fig. 212.—Sample Block Letters.

Fig. 213.—Enlarged Drawing of the Letter G.

centre, all upon the false idea of this being artistic. The first requirement of the printing upon a drawing is that it should be readable; therefore, let it be neat and distinct.

1 2 3 4 5 6 7 8 9 0

Fig. 214.—Samples of Figures.

The heading for the drawing shown at Fig. 209 may be "BLOCK PLAN OF COTTAGE AND GARDEN GROUND." It is rather a long one, and the letter G occurs so often that a special enlarged view of this letter is given at Fig. 213, with the circles completed by dotted lines for comparison, to show exactly the shape that is recommended for this letter.

A sample of the block letters for headings is given at Fig. 212; they may be drawn in single thin lines or thickened to a maximum of $\frac{1}{16}$ in., and on the size of paper recommended—viz., 13 in. by 21 in., their height should not exceed $\frac{5}{16}$ in. for short headings, or $\frac{1}{4}$ in. for long headings. Figures appearing in the heading (Fig. 214) should be the same size as the letters, but as dimensions on the drawing they should not be more than $\frac{1}{8}$ in. deep, nor less than $\frac{1}{12}$ in. When dimensions are put upon a drawing, the distance to which they extend should be carefully shown by dotted lines, with arrow heads at the extremities, keeping the fractions level, as shown (Fig. 79, p. 50), and with the small figures two-thirds the size of the large ones. The feet should be marked by a single accent thus, ′, and the inches by a double accent thus, ″

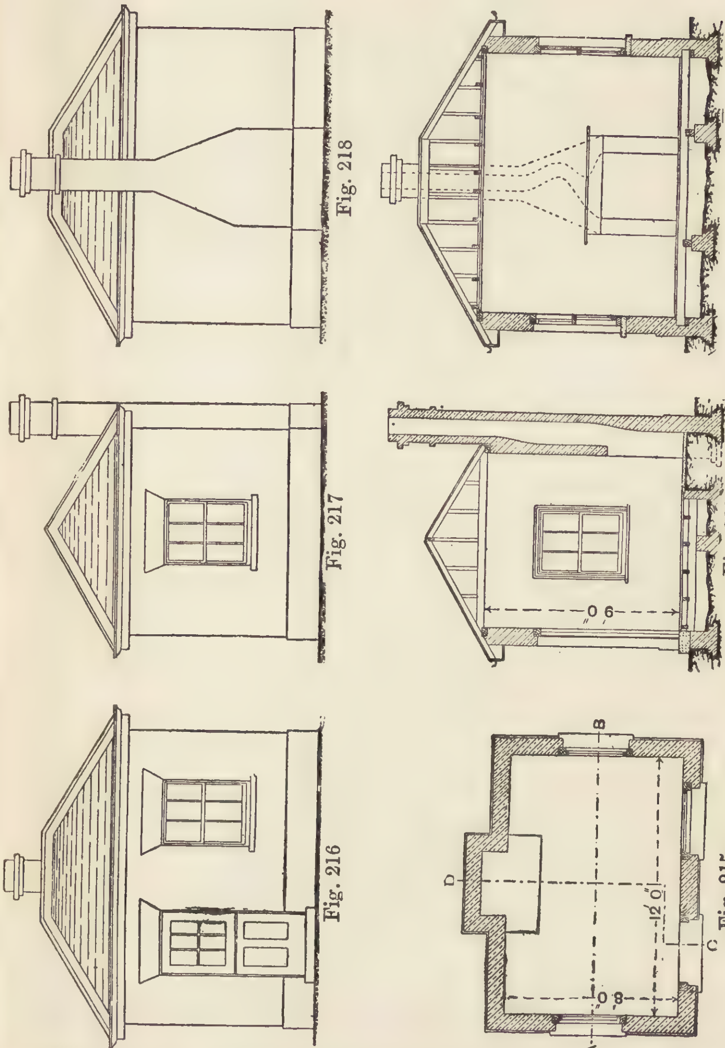
with a full stop on the line between the figures. If the dimensions consist of an even number of feet, then inches should be represented by . O″. The omission has led to serious mistakes in practical work, which should always be guarded against, and, notwithstanding the examples of text-books and the practice of some examiners, this is an important point always observed by practical draughtsmen.

After inking in all the figures, pencil out the heading very carefully, making the letters a little thicker than those used in Fig. 212 ; G, R, S, C, and M will be found the most difficult. The distance apart of the letters should not be quite uniform, but should be such as will look uniform. For example: an I between M and N would require more than the usual space to look right ; on the other hand, a T between L and J would require to slightly overlap to give the right effect. The junction points of A, M, N, V, and W should not be sharp, but the same width as the thickness of the strokes.

Leave ½ in. between the words of the heading, it is then much easier to read than if cramped closer together or spaced wider apart. Remember that the printing—being thicker—will take longer to dry, and be careful not to use the indiarubber too soon. It will be observed that the guide lines for the square, and centre lines for the circle, as described above, have not been inked in, as they would spoil the effect of the drawing, but on machine drawings it is usual to put the centre lines in red, using a little crimson lake for the purpose.

The example on p. 147 shows the usual arrangement of a set of drawings for a house, but in this case the house is of the smallest possible dimensions, and contains one room only. It is about as simple an illustration as can be imagined, but it will form a stepping-stone towards the making of elaborate drawings. A scale of one-eighth of an inch to one foot is the usual scale for complete buildings, upon sheets of imperial paper, 30 in. by 22 in. with details to various larger scales according to the subject, as 1 in., 1½ in., 3 in., and 6 in. to 1 ft., and full size for mouldings.

In drawing the present example, begin with the plan (Fig. 215), as is usual in all ordinary cases, and from that project the front elevation (Fig. 216), then the side elevation (Fig. 217), back elevation (Fig. 218), and sections (Figs. 219 and 220). When finished and inked in, the drawing may be coloured, carefully following the directions given in the chapter dealing with that subject.



Figs. 215 to 220.—Usual Arrangement of a set of Drawings of a House

A draughtsman, before he begins to make his own designs or to draw from actual solid objects, generally makes copies of existing drawings. When these consist of straight rectangular outlines, no particular difficulty is experienced, but when the outline is irregular a beginner may be rather at a loss to know how to proceed. For instance, the outline (Fig. 221) would be copied as shown in Fig. 222. First a horizontal line is drawn from point A, then an arc *a b* of any convenient radius is drawn from point A to cut the horizontal line A B. Select a starting point on the paper corresponding to point A, draw an arc with the same radius A *a*, and take the length of

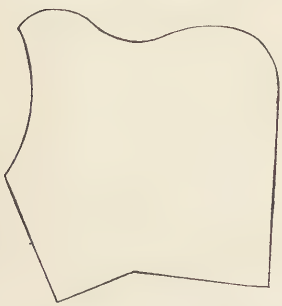


Fig. 221.—Irregular Outline to be Copied.

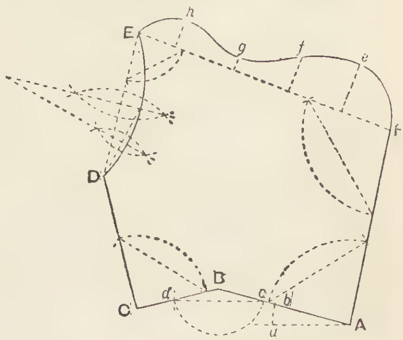


Fig. 222.—Method of Copying an Irregular Outline.

chord *a b* in the compasses, and from *a* on the new drawing cut the arc at *b*, and draw A *b* prolonged, cutting it off at B to the required length. If it were desired to copy the drawing to twice the scale, the lengths of all the lines would have to be doubled, but the angles would be unaltered; similar figures differ in their sides, but not in their angles. Then to copy the angle at B, take any radius B *c* and strike the arc *c d*; upon the new drawing do the same, cutting off the arc to the chord length *c d* and drawing B *c* the right length through *d*; the next angle at C is set off in exactly the same way. The curve D E following requires different treatment, so it will be left for the present and work resumed round the other way. Line A F will be obtained as the previous ones have been, and then a base line is drawn from F to E, leaving all the irregular out-

line on one side of it. The angle and length of this base line will be copied as before, while for the outline the method of distances and offsets will be used. Notice the salient points of the curvature, that is, the most projecting points whether outwards or inwards, as *e g n*; put in short lines at right angles to the base line to meet these points, then copy their lengths and distances from F E, obtaining points *e f g h*. Through these points lightly sketch a continuous curve, afterwards using a French curve and hard pencil for greater neatness. A similar base line, or chord line, may be drawn across the remaining portion D E its length, and the angles F E D are copied as before. This should bring point D exactly where C D terminated; if it does not, it will be well to check the work all through again. Assuming the outline from D to E to be a compass curve, the centre may be found by first bisecting the chord of the whole arc and then the chord of half the arc, the intersection being the exact spot to put the point of the compasses to draw the curve.

If a mere copy of Fig. 221 were desired, much shorter methods might be adopted; the simplest would be a tracing on tracing paper. To obtain a tracing from any drawing, place it on the board with the main lines horizontal and vertical; lay the tracing paper upon it; then cut four pieces of blotting paper, each 2 in. square, fold them twice so as to make pads 1 in. square, and place a drawing pin through one pad at each corner of the tracing paper to hold it firm and prevent it from tearing. Then go over all the lines of the original with drawing pen or pencil, and the tracing will be complete. If tracing linen is used instead of tracing paper, pads need not be used under the drawing pins.

Another mode of copying is to place the drawing over a clean sheet of paper and prick through all the junctions of the lines, and, on curves, some intermediate points also. Then remove the drawing and join up all the pricked points to match the original. Another method is to lay a sheet of carbon paper, or a piece of blackleaded tracing paper, on the blank sheet, place the drawing over it, and then with a blunt point, like a scriber rounded over at the end, trace firmly over the outline of the drawing, which will transfer all the lines on to the blank sheet.

Where the drawing is complicated, or several copies are required, the photographic method is the best way of copying,

giving either white lines on a blue ground, blue lines on a white ground, or black lines on a white ground; the last-named result is the most expensive, but very much to be preferred. In order to be able to produce a good photograph, the drawing must be in very black ink on bluish tracing paper, but a drawing on thin white drawing paper can be copied fairly well.

An instrument which is useful in certain cases for copying drawings is the three-legged compasses. It is like a pair of dividers with an extra leg pivoted at a right angle to the other two, and two of the legs being set upon points as A *a*

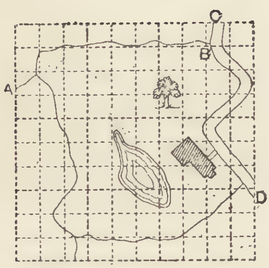


Fig. 223.—Small-squared Plan of Estate.

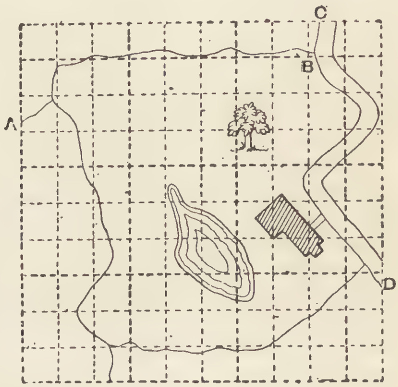


Fig. 224.—Method of Enlarging by Squares.

(Fig. 222); the third is set on B, and the setting is pricked off on the new drawing. Then two being set to A B the third is put on C and transferred. Then two being set upon A C the third is put on D, and so on; or from any given base line any number of points, however placed, may be truly copied.

When a drawing has to be copied to a different scale from the original, there are instruments such as the proportional compasses, the pantagraph, and the eidograph. These, however, are expensive, and must be used with great care to produce a good result. The use of the proportional compasses involves almost as much labour as constructing the

drawing from the commencement, but they are occasionally useful for straight-lined drawings. For estate plans the other two instruments are more appropriate, but practically they can be used for making reduced copies only with any degree of accuracy.

The most draughtsmanlike method to employ for enlarging is that of copying by means of similar squares. Suppose, for instance, a plan drawn to a scale of 60 ft. to one inch has to be enlarged to a scale of 40 ft. to one inch, as shown in the accompanying illustrations (Figs. 223 and 224). Find the largest convenient number that divides without remainder into the two scales—in this case 20, where $40 \div 20 = 2$, and $60 \div 20 = 3$, so that 2 and 3 are the numbers required. Then draw lines horizontally and vertically over the original drawing (Fig. 223) $\frac{1}{3}$ in. apart—that is, three spaces to the inch, making every third line thicker than the others. For the enlargement (Fig. 224) the lines must be $\frac{1}{2}$ in. apart, or two spaces to the inch, and every third line must be thickened as before. As a record of the method, it will be advisable to rule in the squares with Prussian blue or crimson lake, but as their use is only temporary it is not customary for them to appear upon office drawings. Now begin at any part of the drawing, but preferably at the top left-hand corner, as at A on Fig. 223); notice at what proportion of the square the line starts, and then at the corresponding point on the blank form start a line. Notice the direction of the line, where it cuts the next side of the square, and what shape the intermediate portion is. Then follow the line along in the same way through each corresponding square until B is reached. Next go on from C to D in the same way, and so on until all the lines on the original appear upon the enlargement. After dealing in this way with each line, a general view should be taken of the whole, and any noticeable errors corrected, the sides of the buildings being ruled in to straighten them from the sketching.

If a finished drawing is required, the outlines may now be inked in, all the pencilling rubbed out, the different parts coloured or ruled in black and white, and the title put on. Sometimes, to avoid damage to the original, the squares are made upon tracing paper laid over it, and if the copy is only required to be upon tracing paper this might have underneath it a second sheet of tracing paper with suitable squares.

The illustrations on pp. 152 and 153 show conventional signs in use for most of the objects usually indicated on maps. Such conventional signs are in general use for common objects of all kinds.

Tracing forms an important branch of draughtsmen's

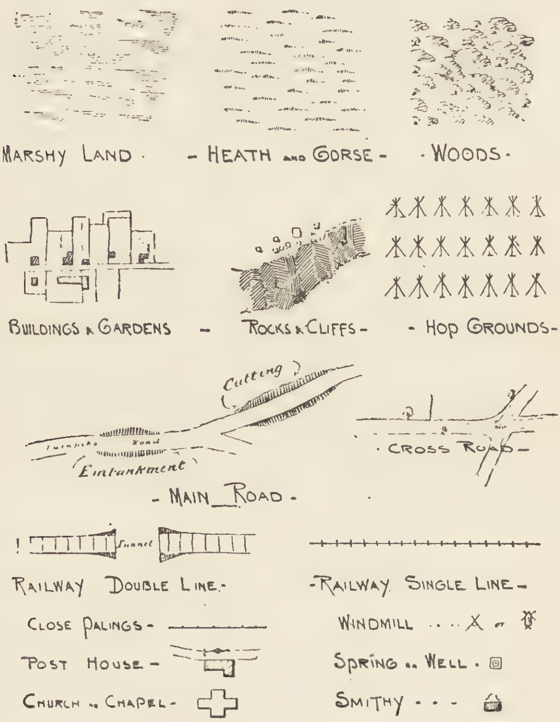


Fig. 225.—Conventional Signs used by Draughtsmen.

work. Tracings are made on either paper, cloth, or linen, paper being used where strength is not important. Tracing paper and tracing cloth is sold in sheets and rolls of varying sizes and lengths. As a rule, the rolls are the more economical to buy. When tracings are required for repro-

duction by any of the blue print processes, paper or cloth of a blue tinge should be selected, as the lines come out clearer than when a yellow tinted material is used. As tracing cloth generally stretches after being cut off the roll, it should be mounted a day before it is required, and stretched again

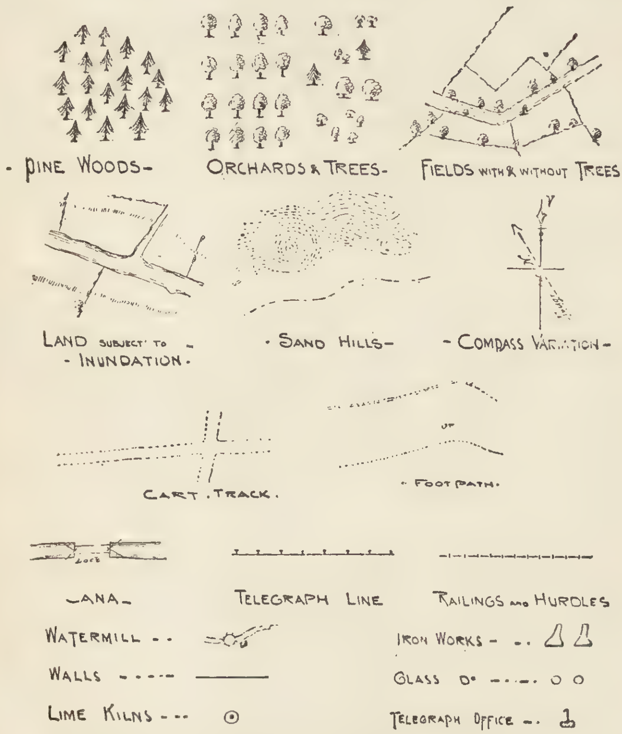


Fig. 226.—Conventional Signs used by Draughtsmen.

to remove the creases. In mounting the tracing paper or cloth over the drawing, pin down the centres first, and work up to the corners.

Tracings in pencil are often made for use in the workshops; when required only temporarily and not to be kept

as a record, or where they will not be subjected to much handling, such tracings are quite sufficient for the purpose. The sections should be tinted on the back of the tracing. It is a good plan to use the pencil and tracing paper when working out a design or a scheme; for instance, the plan of a first floor and successive storeys may be designed on tracing paper over the ground floor plan, and the movements of working parts of machinery can be seen by making paper tracings of the several parts, and moving them to the positions they would occupy in actual work. Tracing paper is also useful when designing ornamental work where any part is repeated. A tracing is made with an H.B. pencil, the tracing turned over and placed on the drawing where the repetition is required, and the lines gone over with a fine pencil or tracing point, which will give a faint impression of the drawing reversed on the paper beneath.

Indian—or, more properly, Chinese—ink is the best for tracing as well as for drawing. The hexagonal sticks, costing about 5s. each, are the best. A few drops of water should be put into a 4-in. saucer, and the ink rubbed up on this with a circular motion, the object being to grind the particles thoroughly. It will take from ten to twenty minutes to prepare a saucer of ink. A little experience will enable the operator to determine the required thickness, the consistency of the liquid being judged from time to time by blowing on the surface. When too thin the ink will make a grey line, and if too thick will not flow freely from the pen. For drawing on paper of which the surface has to be washed over with colour, a little bichromate of potash should be rubbed up with the ink, a piece the size of a pin's head being used for a saucer; but care must be taken with this material, for if much is put in a yellow smear will stain the paper on each side of the lines. If the tracing cloth or paper has a greasy surface, a small quantity of prepared ox-gall or soap is rubbed up with the ink; but it is better, when possible, to avoid using these, and to dust over the surface of the tracing with whiting, all of which must be rubbed off with a clean duster. The saucer containing the ink should be kept covered with another saucer, which should be removed only for dipping in the pen. Liquid inks to be bought ready for use are very convenient.

Drawings during progress should be protected from dust as much as possible, for in spite of all care that can be taken, it will be certain to be more or less soiled by the rubbing of the T square and set-squares. These should always be dusted before use, and when the drawing is not being worked on it should be covered over with a sheet of paper. Brown paper is commonly used for this purpose, and in most cases is suitable enough ; but for very fine work it is said to be objectionable, on account of its tarry nature. Newspaper is apt to leave the marks of printers' ink. If the drawing is one which is likely to occupy a long time before completion, a sheet of paper should be gummed or pinned to the board, covering the whole of the paper, and arranged so as to expose only the portion of the paper which is required for immediate use. This can be done either by folding back the paper or by cutting out small squares, and patching them up again when that portion is drawn. After the drawing is quite completed, it should be cut off the board with a sharp penknife and a steel straight-edge. A shoemaker's knife is a useful tool for this purpose, as well as for cutting cardboard and other work of a similar nature in the drawing-office.

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